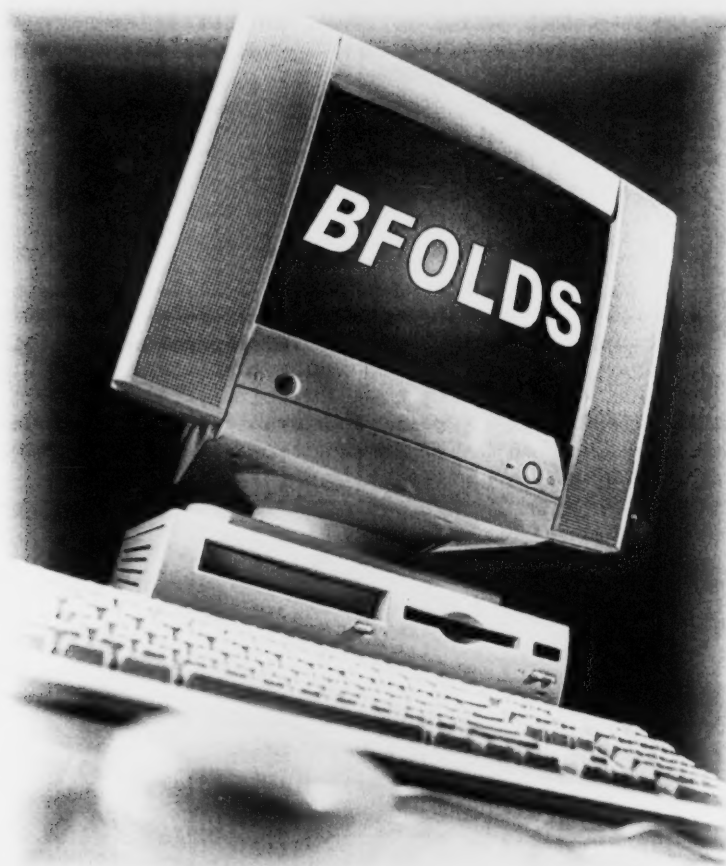


BFOLDS 1.0:

A user's guide to the software package



Version 1.0.0

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A user's guide to the software package

by

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2008

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1. Introduction

The objective of this document is to explain how to use the BFOLDS 1.0 software package. This software package contains the model BFOLDS version 1.0 (*Boreal Forest Landscape Dynamics Simulator*), and the toolbox that supports the user to apply the model and conduct many data-based tasks through a graphic user interface (GUI). This software package can be accessed at <http://www.fire-regime-model.com/>.

The guide is organized into two sections. The first section addresses the data requirements of the model, including the types of data required and their format as well as possible sources.

The second section provides detailed instructions for how to install BFOLDS 1.0 software and use its GUI to parameterize the model and conduct simulations. This section also describes how to extract data from simulations and conduct secondary analyses of fire regime and forest succession. Although describing every detail involved in assembling data and parameterizing a complex model such as BFOLDS is not possible, an attempt is made here to address the major steps and decision points.

The expectation is that a reader of this report is well versed in GIS and possesses basic computing skills to understand and execute the data management steps that are *not* described in this guide.

This document complements the report that describes what BFOLDS is, its scientific principles, how it works, and its appropriate uses. That report, *BFOLDS 1.0 – A spatial simulation model for exploring large scale fire regimes and succession in boreal forest landscapes*, provides the context for many of the details provided in this guide. Therefore, it is strongly recommended that all BFOLDS users read and understand that document prior to reading this user manual and using the software.

The contents of this user's guide will change with time, as the toolbox in BFOLDS 1.0 expands. Therefore, the reader is urged to periodically check the BFOLDS website (<http://www.fire-regime-model.com/>) for updates.

2. Data and input requirements for BFOLDS 1.0

To use BFOLDS, someone with GIS expertise must create the input data needed. The information below will help users to understand what BFOLDS 1.0 requires.

2.1. *Spatial data requirements*

BFOLDS can use many spatial data layers. During simulations, these layers control model behaviour, such as fire spread, or control user assumption selections. Following are descriptions of the spatial data layers that BFOLDS can use, their roles in BFOLDS and the BFOLDS toolbox, and where appropriate, their source.

Many of the examples, maps, and images are specific to Ontario Ministry of Natural Resources's (MNR) use of BFOLDS; therefore, some descriptions of data and terms used may be MNR-specific.

However, BFOLDS 1.0 is a generic tool, and it has been designed to use data from sources other than Ontario and MNR.

2.1.1. Study area and buffer

Before preparing data for BFOLDS, users must define coordinates of their study area. They should include an external buffer (with data), to account for the effect of fires that spread in and out of the study area.

Including buffer data is not always possible; for example, the data outside the study area may not be available or may not be compatible. In such cases, users must approximate data for buffers as best as they can, for example by duplicating study area data in the buffer. Because simulated patterns in the buffer are not included in data analyses and interpretation, this does not cause a problem.

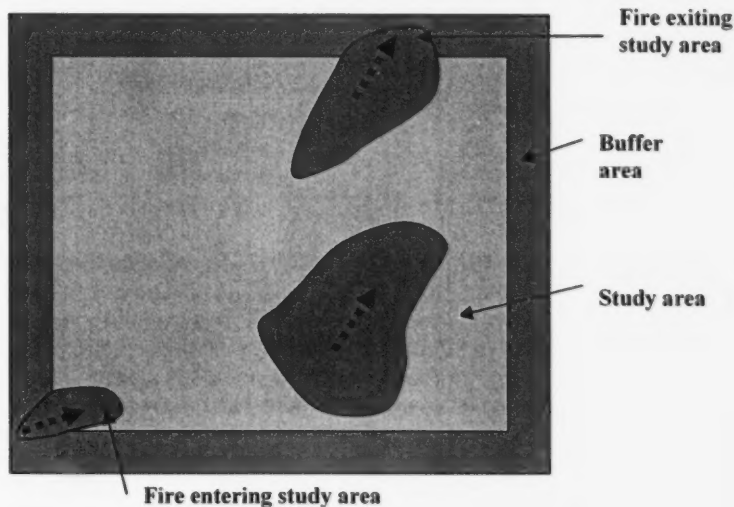


Figure 1. An example study area showing fires originating within and spreading from (and to) the buffer area.

The size of the study area that BFOLDS can simulate is limited by users' computer memory and by the amount of memory a 32-bit Windows program can address. BFOLDS can use a maximum of 2 gigabytes of memory. The maximum area that will fit into memory is 17 to 20 million ha (including all the *no-data* areas as described below), depending on the complexity in user assumptions. Because BFOLDS uses raster data, the shape of area simulated within BFOLDS must be rectangular, regardless of the actual shape of the study area. The area that falls outside the study area becomes *no-data*.

Role in BFOLDS: Study area information allows BFOLDS to determine the area's extent and to validate the other data layers.

2.1.2. Forest cover

For each pixel, the dominant canopy type defines the forest cover for the whole pixel. A pixel in BFOLDS cannot contain more than one forest cover type (e.g., 50% Forest Cover A, 50% Forest Cover B is not possible).

Information on forest cover supersedes all other data layers. If a pixel in the forest cover layer has a valid value (not no data), then all other data layers must contain a valid value for that pixel. This is verified by BFOLDS and data layers that do not meet this requirement will not be imported.

BFOLDS 1.0 allows up to 30 forest cover classes.

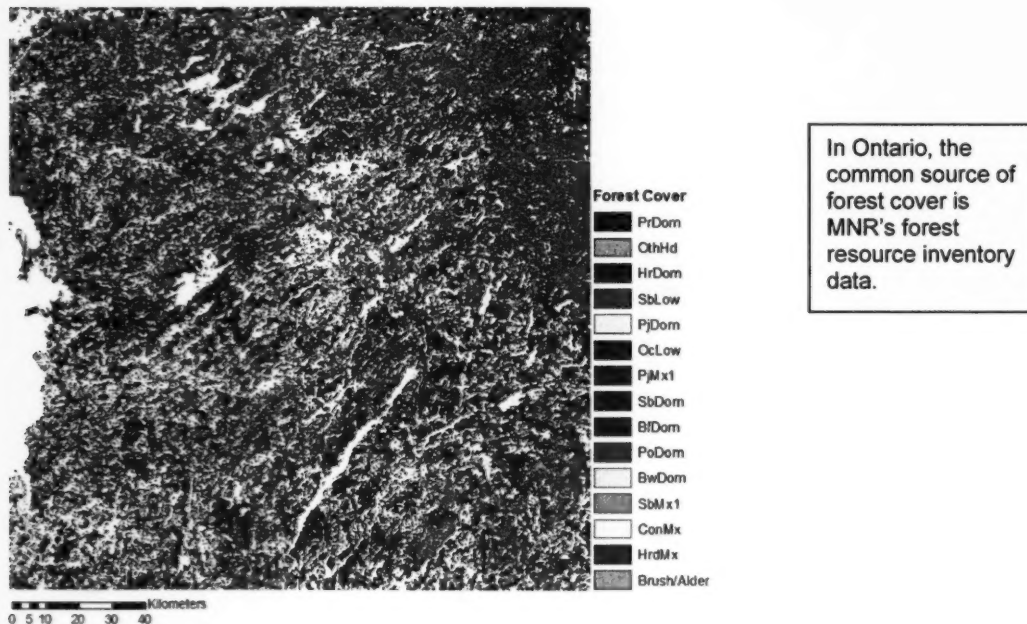


Figure 2. Example of forest cover data used in BFOLDS. This example is based on forest unit classification by the Ontario Ministry of Natural Resources' Northwest Region.

Role in BFOLDS: Forest cover defines where BFOLDS fire and succession processes can occur (forested land) and where they cannot (non-forested areas such as water, wetlands, and urban areas). Based on user assumptions, BFOLDS translates forest cover classes into fuel types and combines them with data on fire weather conditions and terrain to simulate fire spread. Forest cover classes are linked to forest cover succession rules to simulate post-fire and natural succession processes. Forest cover data is also an output.

Sources: BFOLDS can use forest cover data from various sources (e.g., classified satellite imagery, aerial photography, ground surveys), assuming that the final data layer is created at 1 ha resolution and has 30 or fewer forest cover classes.

2.1.2.2 Forest cover age

BFOLDS uses two types of age data: canopy age and site age. All pixels with a valid forest cover type must have an age value greater than 0. In BFOLDS, the dominant forest canopy age defines the forest canopy age layer. Site age is the time since last fire.

By default, in Year 1 of a simulation, BFOLDS uses the forest canopy age layer for site age as well because, in most cases, reliable information about site age is not available. If users have site age information, they can enter it as a separate data layer.

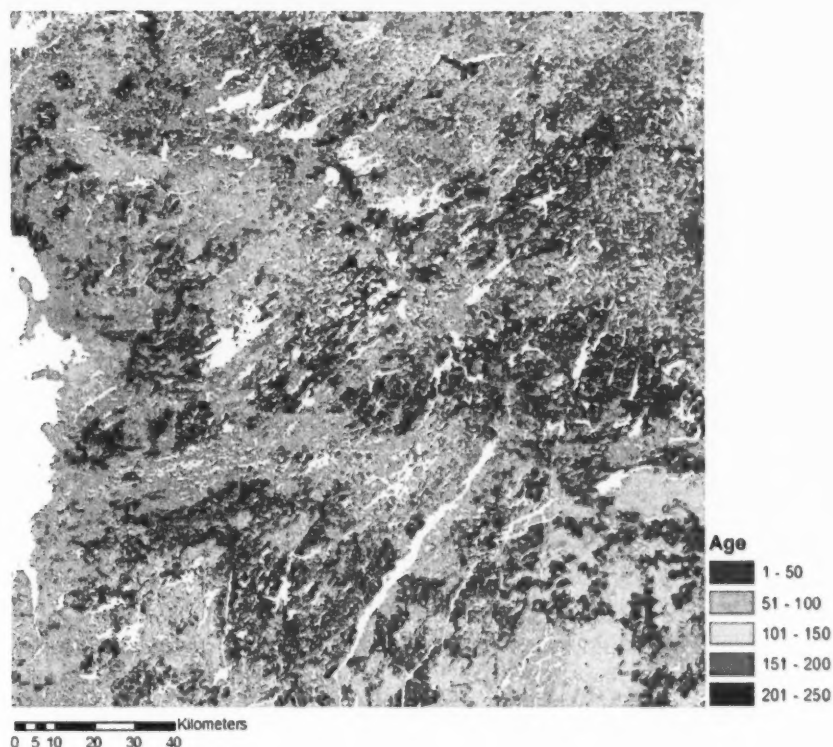


Figure 3. Example of forest cover age data used in BFOLDS.

Role in BFOLDS: During a simulation, BFOLDS updates layers for forest canopy age and site age. These data influence fire spread by determining fuel types and natural forest succession by guiding selection of forest cover transition rules. As well, both types of forest cover age are a simulation output.

Source: BFOLDS can use forest cover age data from any source, as long as users can assign an age for each pixel that has a valid forest cover value.

In Ontario, the common source of forest cover age is MNR's forest resource inventory (FRI) data.

2.1.3. Terrain

BFOLDS requires two data layers related to terrain: slope and aspect.

The slope data represent continuous values of percentage slope calculated directly from a digital elevation model, at 1 ha resolution. The aspect data represent continuous aspect values ranging from 0 to 359, with -1 representing flat areas with no aspect, such as lakes. In most cases, users calculate aspect from a digital elevation model.

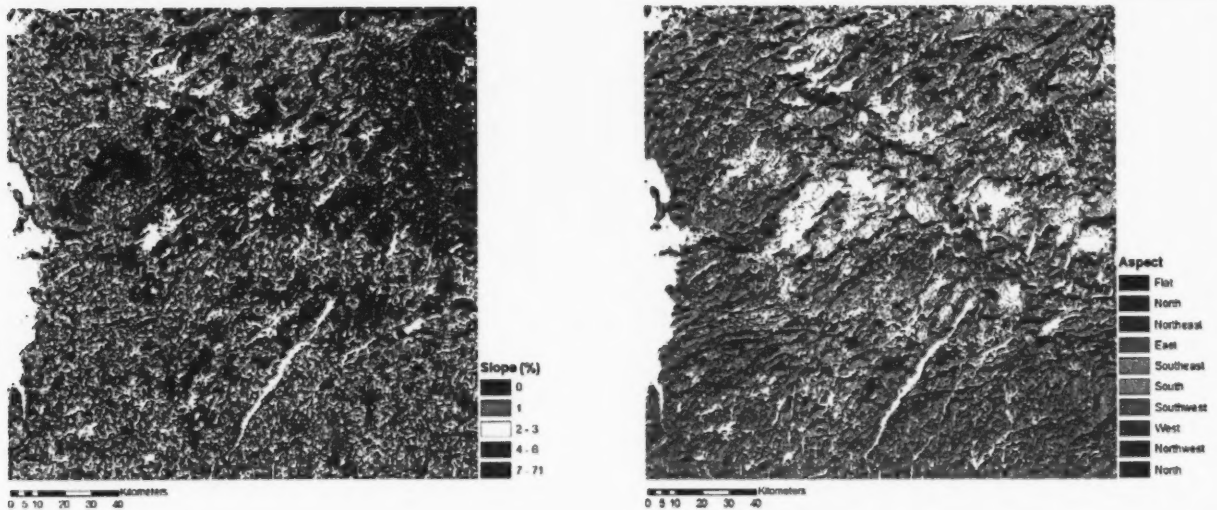


Figure 4. Example of percentage slope and aspect data used in BFOLDS. Classes shown for slope are for display; actual data contain continuous values.

Role in BFOLDS: Slope and aspect are critical components of the fire spread algorithm.

Source: Users derive slope and aspect from a digital elevation model. BFOLDS can use data from other sources, as long as users generate a 1 ha resolution ASCII image for percentage slope and aspect.

In Ontario, a digital elevation model that can be used to derive slope and aspect is available as a National Topographic Series (NTS) map sheet from the Canadian Centre for Topographic Information (2000) at <http://www.geobase.ca>.

2.1.4. Strata

Depending on the study area and its size, BFOLDS can use other details about the study area, beyond what was specified above. To accommodate those, BFOLDS allows users to input up to five layers of other data. These data layers further stratify the study area during simulations.

Data that act as strata are generic and users assign values based on their knowledge of the study area. These layers are hierarchical with zones at the highest level and a series of site factors at lower levels.

2.1.4.1. Zones

In some cases, users may believe their study area has broad patterns of geoclimatic heterogeneity and thus can be divided into zones, each with its own set of fire and/or forest succession processes. Users can create a zone GRID so BFOLDS can select different fire or succession assumptions based on the zones. BFOLDS allows up to 10 zones within a study area.

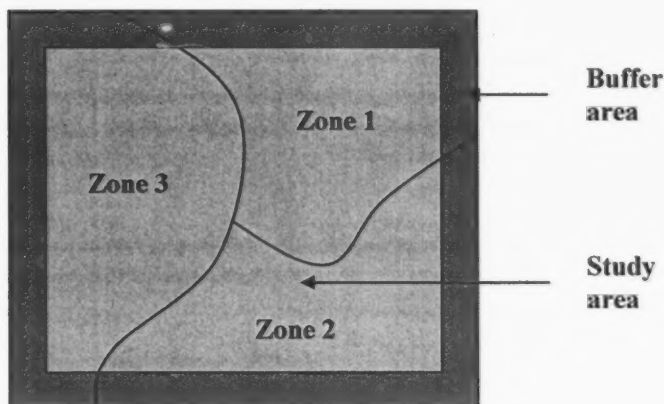


Figure 5. Example of zones within a study area.

Role in BFOLDS: BFOLDS uses zones as the primary criteria for spatially stratifying application of model parameters, such as forest cover succession rules, as well as data conversion procedures, such as translating forest cover types to fuel types.

Source: No single source, decided by user; examples include eco-regional classifications or forest regions.

2.1.4.2. Site factors

Users may include up to four other data layers (in addition to zones), as ASCII GRIDs, to inform model functions. The valid values for these grids are 1 to 5. Examples of site factors are *direct* data layers, such as soil moisture and soil nutrients, and *derived* data layers, such as site classes and eco-sites. These factors act as "by" variables to help users further refine forest succession rules, forest cover mortality threshold rules, and forest cover to fuel type conversion rules.

Role in BFOLDS: *BFOLDS can use these ASCII GRIDs to select fire and succession user assumptions.*

Source: No one source, decided by user; examples include soils classifications or site classifications.

2.1.5. Spatial biasing regions for succession

Spatial biasing for succession is determined by spatial correlation among site factors, for example soil moisture and nutrients, that are assumed to form homogenous site conditions. Correlation measures need to be estimated for each site factor layer, averaged, and then grouped into one of four classes as follows:

1. Non-positive correlation
2. Low positive correlation
3. Moderate positive correlation
4. High positive correlation

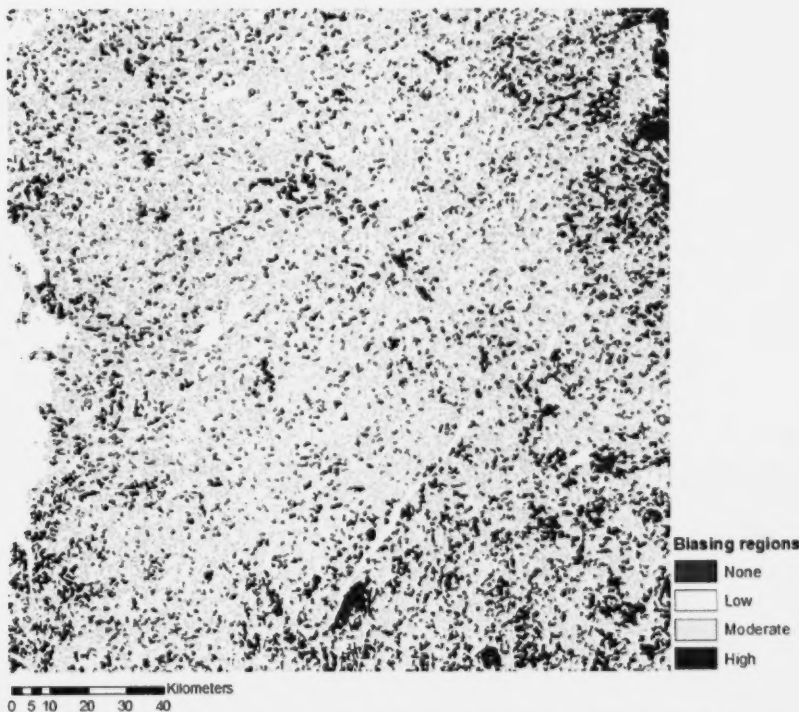


Figure 6. Example of biasing regions for succession within a study area.

Role in BFOLDS: *Biases the assignment of transition probabilities in the succession model based on spatial correlation.*

Source: No one source, decided by user; Data is based on the site factors and their spatial relationships. Contact flep@ontario.ca for procedures to create the biasing regions.

* For details see pages 40-42 of *BFOLDS 1.0 – A spatial simulation model for exploring large scale fire regimes and succession in boreal forest landscapes*.

2.1.6. Latitude and Longitude

BFOLDS requires latitude and longitude data layers to interpolate weather data for use during fire simulation. The grid must be in float format.

Role in BFOLDS: *Used during fire simulation to retrieve local fire weather for pixels.*

Source: User input based on the latitude and longitude for each pixel in the study area.

2.1.7. Ignition count

BFOLDS requires information about ignition as an ASCII text file containing the year, Julian day, and expected number of ignitions within the study area (as in Table 1).

Table1. Example of partial input file for number of ignitions within a study area.

Year	Day (Julian)	Ignitions (#)
1	185	1
1	186	0
1	187	0
1	188	0
1	189	7

Role in BFOLDS: *Used to seed fire ignitions during fire simulation. Users must provide this data for all weather years and weather days (for more information, see Section 2.1.9).*

Source: No one source, decided by user based on historical weather data or assumed from other sources.

2.1.8. Spatial biasing for ignitions

Users may select the option to spatially bias the seeding of fire ignitions. This requires a data layer that will spatially weight the probability of ignitions within the study area.

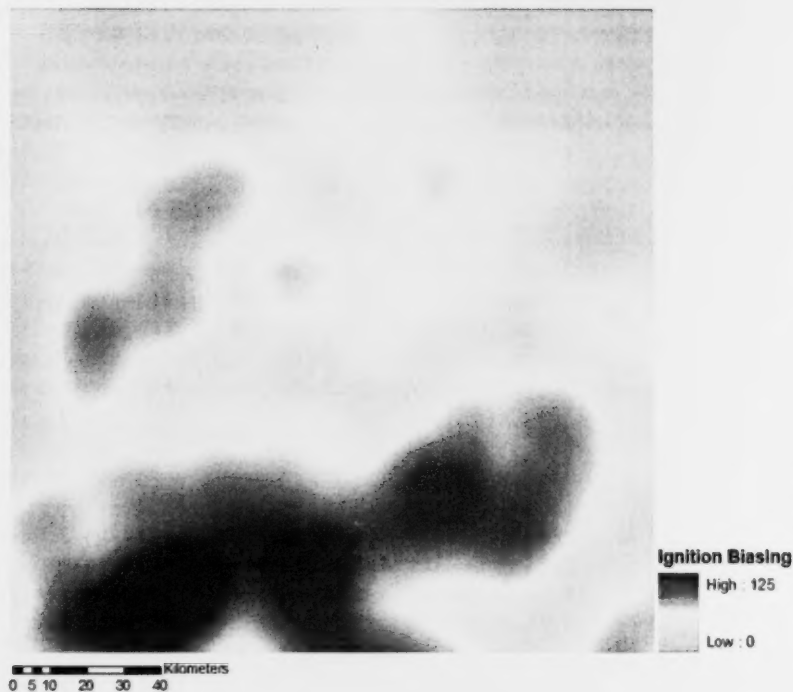


Figure 7. Example data layer that guides spatial biasing for ignitions.

Role in BFOLDS: *Used for spatially seeding fire ignitions during fire simulation.**

Source: No one source, decided by user based on historical weather data or assumed from other sources.

* For details see pages 28-29 of *BFOLDS 1.0 – A spatial simulation model for exploring large scale fire regimes and succession in boreal forest landscapes*.

2.1.9. Fire weather

BFOLDS allows users to import weather data streams (as point data) for simulating fire. This data must be in the following format:

- Point ID (integer)
- Latitude and longitude of point (decimal degrees)
- Year (integer)
- Julian day (integer)
- Temperature (Celsius, to one decimal point)
- Relative humidity (% , integer)
- 24 hour precipitation (mm, to one decimal point)
- Wind speed (km/h, integer)
- Wind direction (direction wind is from, in degrees from 0 to 359 clockwise, where north = 0)

As well, these must meet the CFFWIS (Canadian Forest Fire Weather Index System) standard for fire weather data. For example, they must represent weather at 1300 daylight time, and a 10-minute average wind speed.

Users may provide this data based on:

- Past weather record information (points represent real weather stations), and/or
- Assumed (e.g., climate models) weather information (points represent simulated weather stations)

Table 2 presents an example of a weather data set that is formatted for BFOLDS. The PointID refers to an actual weather station or a point for which user inputs weather.

Table 2. An example of required weather data for simulating fire regime in BFOLDS

PointID	Latitude	Longitude	Year	Julian day	Temperature (C°)	Relative humidity (%)	Precipitation (mm)	Wind speed (km/h)	Wind direction (degrees)
1	52.5321	-94.5931	1	1	30.3	20	2.1	15	15
2	51.5381	-97.7894	1	1	27.1	35	5.9	27	295
3	52.7956	-96.6023	1	1	26.9	23	0	22	0
1	52.5321	-94.5931	1	2	10.7	45	10.4	15	105
2	51.5381	-97.7894	1	2	12.2	15	4.1	27	125
3	52.7956	-96.6023	1	2	16.5	10	0	22	132

BFOLDS uses the tab delimited file of a weather data table (not including headers) to import weather data.

Users must ensure that for every Julian day, at least 3 points of weather information are available for the study area (to a maximum of 200 points), with specific spatial coordinates.

Figure 8 shows a hypothetical study area, with the circles representing possible locations of weather data points. While all 3 scenarios are valid, Scenario A is useful only if points are not too distant (relative to the size of the study area) from the study area. Scenario A uses interpolation within the known extent of the data, B extrapolates beyond, and C is too clustered to provide adequate information for the NW corner of the study area. Scenario C is problematic because a non-linear surface is fitted to the fire weather indices, so extrapolation away from the data can be erroneous.

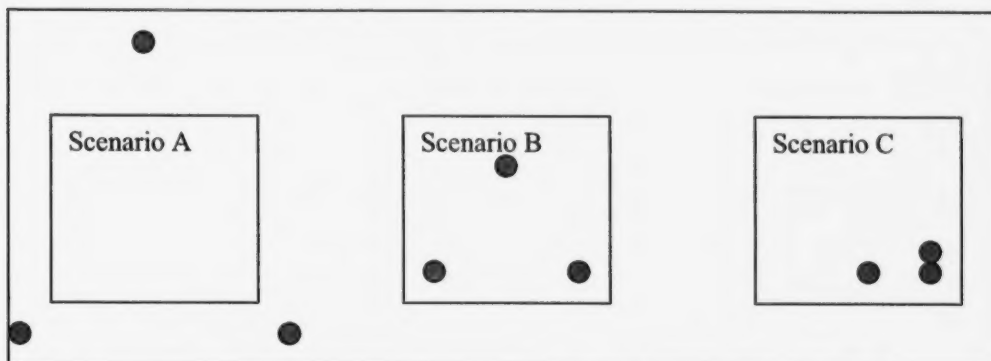


Figure 8. Examples of study area scenarios with locations of weather data points (red circles)

Other important points about weather data:

- When collecting or generating the point data, the information on a point must contain separate entries for each weather day.
- The weather point locations can differ from day to day.
- When simulating a fire season from Julian day 90 to 300, weather data are required for all of those days.
- Weather data are not required for days outside the fire season.
- Users can select how BFOLDS applies the weather details in fire simulations: The model can use a series of weather data years in sequence or select randomly (as a uniform or biased distribution) among years in a single weather series.
- Users must provide daily ignition count data for the complete period of weather data.

The above weather data is then splined and imported into a BFOLDS project (contact flep@ontario.ca for the appropriate splining procedures).

2.2. User assumptions

User assumptions are critical to BFOLDS simulations of fire and succession processes.

User is strongly encouraged to be aware of the importance of the user assumptions for BFOLDS simulations.

For details, see pages 4, 32, 43, and 47 in *BFOLDS 1.0 – A spatial simulation model for exploring large scale fire regimes and succession in boreal forest landscapes*.

2.2.1. Fire simulation

BFOLDS expects users to input rules to convert forest cover to forest fuel types, which influence simulations of fire ignitions and their spread. Users can specify these rules for spring/fall and summer along with the dates of the start and end of fire seasons.

2.2.1.1. Forest cover mortality threshold

These threshold rules allow BFOLDS to determine fire intensity values that indicate when the forest cover on a burned pixel can be considered destroyed. The BFOLDS default for forest cover mortality threshold is 0 kw/m² (meaning forest cover on all burned pixels is destroyed).

Users define mortality threshold levels by providing data for:

- Forest cover (required)
- Maximum forest cover age (required)
- Zone (optional)
- Site factors (optional)

For examples of how to create these rules using the *Forest cover mortality threshold* editor, see Section 3.6.3.2.

2.2.1.2. Forest cover to forest fuel conversion

Rules that govern forest cover to forest fuel conversion indicate which types of fuel types are interpreted from given forest cover types. To determine the forest cover to fuel type conversions, users must provide the following data:

- Forest cover (required)
- Maximum forest cover age (required)
- Zone (optional)
- Site factors (optional)

For each forest cover type, users must provide at least one corresponding fuel type. If they have more detailed information, they can create additional rules that account for the other factors.

For examples of how to create user assumptions using the *Forest cover to forest fuel* editor, see Section 3.6.3.3.

2.2.1.3. DMC threshold and range for fire extinguishment

BFOLDS uses a DMC threshold value to determine when fires should be extinguished. Simulated fires that are spreading or smoldering will extinguish when the DMC for a cell is equal to or less than the threshold value. A range for the threshold values around a mid point can be entered as a percentage (for example $20 \pm 10\%$). These values are entered while creating a parameter set (see Section 3.7.1).

2.2.1.4. Fire season dates

BFOLDS uses a series of dates to determine the commencement, to changes and end of the fire season during simulations. They are:

- Start date — to signal the commencement of the fire season
- Summer season start date -- to signal the end of spring and commencement of summer season
- Summer season end date -- to signal the end of summer and commencement of fall season
- Fire season end date -- to signal the end of the fire season

These values are entered while creating a parameter set (see Section 3.7.1).

2.2.2. Forest succession

BFOLDS uses two types of succession rules, post-fire establishment and natural succession. Each set of succession rules has the same data format, but the natural succession rules also have an age element. Users must input a third set of rules that determine forest canopy aging.

2.2.2.1. Post-fire establishment

In BFOLDS, post-fire establishment occurs immediately after the fire season. Any pixel that was considered destroyed based on the forest cover mortality threshold (see Section 2.2.1.1) will undergo post-fire establishment and BFOLDS will select a replacement forest cover.

Users can define different post-fire establishment rules by separating them by:

- Forest cover (required)
- Zone (optional)
- Site factors (optional)

For each forest cover type, users must provide at least one entry. Use of zones and/or site factors will provide more detailed information.

For examples on creating rules using the *Post-fire establishment* editor, see Section 3.6.4.1.

2.2.2.2. Natural succession

Any pixel is eligible for natural succession once its canopy age reaches the first time step (5, 10 or 20 years, as assumed by the user). After that, pixels with forest cover will be eligible again for succession based on the time step assumed by user. BFOLDS applies the succession probabilities that users input for each forest cover type (at 5, 10 or 20-year intervals) up to a maximum of 400 years. When a forest cover type's canopy age exceeds 400 years, BFOLDS defaults to the probability values assigned to age 400.

Users can define different natural succession rules by separating them by:

- Forest cover (required)
- Zone (optional)
- Site factors (optional)

For each forest cover type, users must provide at least one entry. Use of zones and/or site factors will provide more detailed information.

For examples on creating these rules using the *Natural succession* editor, see Section 3.6.4.2.

2.2.2.3. Forest canopy aging

When a pixel succeeds to a new forest cover type, BFOLDS assigns a canopy age, which must be less than the site age. The forest canopy rules allow users to control the incoming age of a pixel as well as the maximum age a pixel can attain. If a pixel reaches the maximum age before it undergoes succession, then BFOLDS resets it to the incoming age.

For examples on creating these rules using the *Forest canopy aging* editor, see Section 3.6.4.3.

2.2.2.4. Spatial biasing for succession

Spatial biasing for succession allows a group of pixels to act as aggregates through time. This biasing procedure influences how BFOLDS modifies its application of succession rules to pixels that are burned or are eligible to change due to aging.

For more information about spatial biasing for succession, see the document that describes what BFOLDS is and how it works (Perera et al. 2008; *BFOLDS 1.0 – A spatial simulation model for exploring large scale fire regimes and succession in boreal forest landscapes*).

Region weights

Region weight values determine the degree to which spatial biasing routines modify application of the forest succession rules. Users can select from the following weights:

- Low ($\frac{1}{4}$)
- Medium ($\frac{1}{3}$)
- High ($\frac{1}{2}$)

Maximum probability

Users can decide the maximum probability value in succession matrices that can be influenced by region weights (explained below) during spatial biasing routines. The default value is 1, which allows BFOLDS to modify any probability values >0.

For example, if users set the maximum probability to 0.5, then BFOLDS will not modify any value >0.5.

2.2.3. Simulation period

Simulation period could be as long as 400 years, but it is recommended to use periods shorter than 300 years. Longer periods may result in unrealistic model assumptions (for example, about species migrations, extremes in weather patterns, lightning ignition patterns, etc.).

2.3. Data preparation

Before preparing data, users must determine and delineate the final study area to ensure all spatial data entering BFOLDS and the BFOLDS toolbox are created consistently.

After deciding on the study area and the buffer (Section 2.1.1), users must produce two basemaps (Table 3) for preparing the BFOLDS ASCII files. These basemaps are created manually by a coverage or by basing them on existing boundaries, such as MNR ecoregions in Ontario. The first one, *BFOLDS run* is used by the BFOLDS toolbox. The second, *BFOLDS selection raster*, helps to ensure that all the input data covers the same extent.

Table 3. Details of basemaps required for BFOLDS.

Basemap	Purpose	Extent	Format	Attribute
<i>BFOLDS run</i>	Template for input into BFOLDS toolbox	Analysis area and buffer if available	ASCII	Value=1 and 2 for buffer
<i>BFOLDS selection raster</i>	Used to cut data	Analysis area and buffer if available	GRID	Value=1

All required datasets must use the same projection. All data used for Ontario has a projection of NAD 1927 Lambert Conformal Conic, which is MNR's standard.

When creating these basemaps, users must remember that all images require valid data for each pixel where forest cover exists. Shoreline areas may be a problem if created using different basemaps or in different projections. For example, the spatial position of a shoreline may differ among maps used to provide input for various BFOLDS data layers. If this is the case, users can draw the base grids to include only the common area along the shoreline.

3. Installing and using BFOLDS 1.0

3.1. Hardware requirements

Any computer that has a processor running at 1 GHz or higher can use BFOLDS 1.0. The main requirements are computer memory and storage space. The more RAM and the faster the processor, the faster the simulations will run. The hard drive should have at least 200 GB of free space to store the simulation output.

The recommended computer specifications apply to the time this guide was published. The **minimum** requirements are:

- Pentium 4 or AMD Athlon XP processor running at 1 gigahertz or higher
- 512 megabytes of RAM
- 15 megabytes of available disk space for compact install (excluding memory required for output storage)
- Mouse or other pointing device
- Display resolution of 1280 by 1024 pixels

BFOLDS 1.0 will work with a 64-bit processor, such as the Athlon 64 or Intel Core Duo or newer, but will still use a 32-bit address space and, therefore, will remain limited to 2 GB of RAM.

3.2. Software requirements

Operating system:

- BFOLDS 1.0 requires Windows 2000, XP Home, or XP Pro
- It will also work with more recent versions of these programs.

Other required software:

- Microsoft .NET framework version 2.0 or higher
- ArcGIS or other GIS software (to prepare the primary data)

Space requirements for simulations:

- BFOLDS needs approximately 130 megabytes of memory for every million ha in the study area.
- Note that when GRIDs are developed, they occupy a rectangular area. This is true for all the input layers. The unused areas of the rectangles will use memory even though they are not part of the study area.
- Compressed data output occupies 120 megabytes of space for every million ha or about 1.5 to 2 gigabytes for uncompressed output per 200-year repetition.
- The maximum area that BFOLDS can process is about 18 million ha, depending on the complexity of the user assumptions.

Table 4 provides 2 examples of the amount of memory/storage space that BFOLDS will use for a 200-year simulation with 1 repetition.

Table 4. Computer memory requirements for using BFOLDS.

Example study area size	Memory used	Output space required when compressed
3 million ha	500 megabytes	800 megabytes (200-year simulation)
15 million ha	1,700 megabytes	4,500 megabytes (200-year simulation)

3.3. Installing BFOLDS

Installing BFOLDS 1.0 is similar to installing any other Windows application: Run the setup file from the DVD provided (available by e-mailing flep@ontario.ca) or from a file downloaded to the hard drive.

When installing updates to BFOLDS or BFOLDS toolbox, first make sure that these programs are not running.

3.4. Starting and activating BFOLDS 1.0

BFOLDS toolbox has an activation feature that is linked to the user's computer. This informs the model developers who is using BFOLDS 1.0 to ensure that users receive information on future updates and timely technical support.

Activating BFOLDS toolbox

To activate BFOLDS toolbox, the user must:

1. Select the *BFOLDS toolbox* shortcut in the *Start* menu to open a registration window.
2. Send an e-mail to flep@ontario.ca that includes the

user name and the machine name as listed in the activation dialog box.

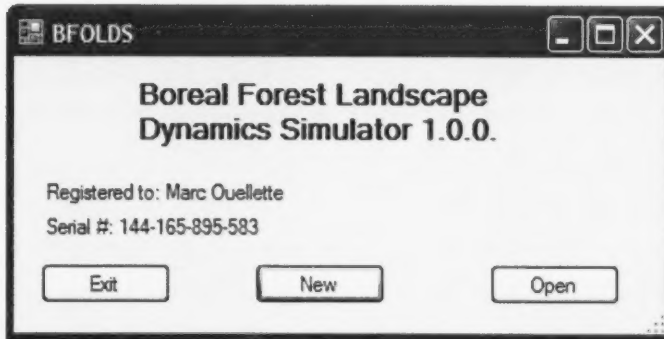
3. Select the *Exit* button to close BFOLDS toolbox.
4. Watch for an email that contains a serial number (the e-mails are usually sent within 24 hours, Monday to Friday); start BFOLDS again and enter:
 - i. The user name, exactly as typed in the e-mail
 - ii. The user e-mail address

iii. The serial number provided in the return e-mail

5. Select the *Activate* button.

If the user enters the activation information accurately, BFOLDS 1.0 will register with the user's system and this step need not be repeated.

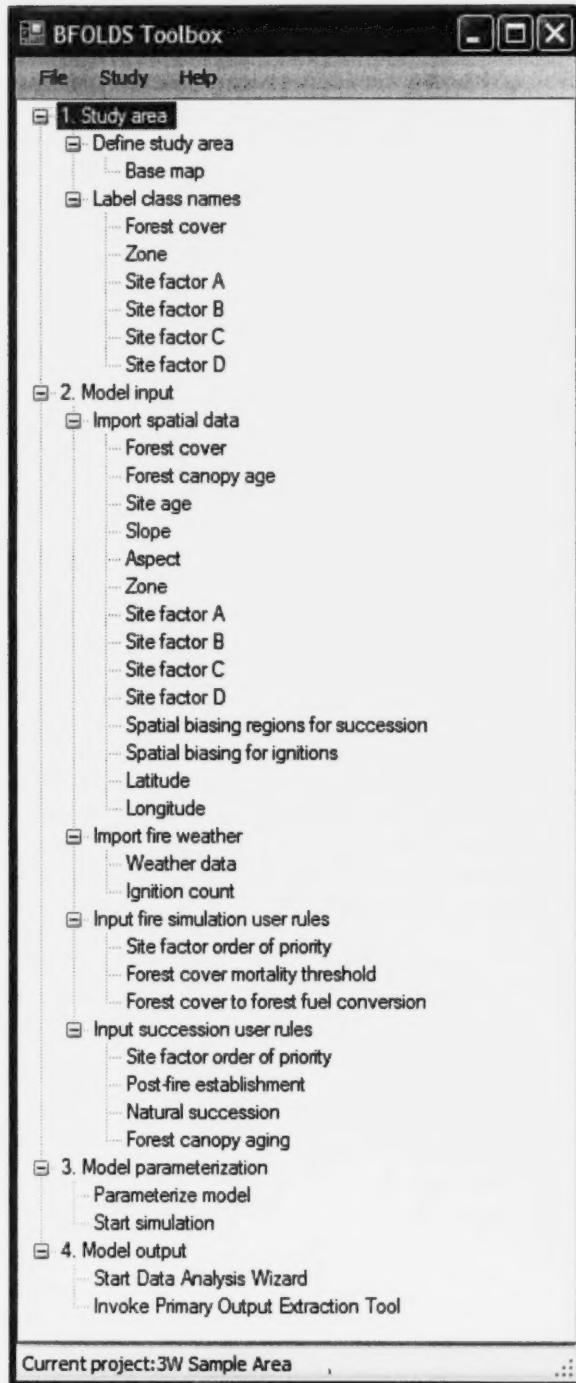
The next time the user starts BFOLDS, a registration window will display (see example below), followed by the main BFOLDS toolbox window.



BFOLDS uses a version-numbering system that has three numbers:

- The first number indicates the architecture of the model. It will change only when the design or science content of BFOLDS are modified significantly. Such a change will include an update to all documentation.
- The second number indicates minor changes in science content and algorithms of BFOLDS. Such changes may involve addendums to documentation.
- The third number indicates content changes that improve model performance but do not affect science content. These do not warrant documentation updates.

BFOLDS toolbox



BFOLDS toolbox (see main menu at left) gives the user access to a range of tools available to create a new study, as well as to view, edit, and modify user assumptions and data.

BFOLDS toolbox will continue to expand in the future to include new features. For the most up-to-date information, the user should check the *Help* file included with the BFOLDS toolbox or contact the Forest Landscape Ecology Program for updates at flep@ontario.ca.

When the user starts BFOLDS toolbox, a window will display that presents two options: *Create* to start a new study or *Open* to work on an existing study.

Important: A study consists of all the spatial data, user assumptions, and model parameters needed to use BFOLDS. A study cannot include data for two different locations. In addition, spatial data for each study must be of the same extent.

In any BFOLDS toolbox window, the user can view the *Study* menu, which provides access to information, history, or documentation about the study area.

Study information

The screenshot shows a 'Study Information' dialog box. It has a title bar with a close button. The fields are as follows:

- Name:** Test Study
- Folder:** C:\temp\3E Sample (with a browse button)
- Simulation goal:** Fire and succession (selected from a dropdown menu)
- Description:** Sample data to use for BFOLDS testing (in a text area)

At the bottom are 'Cancel' and 'OK' buttons.

If the user selects *Create*, the above window will display. Then user must:

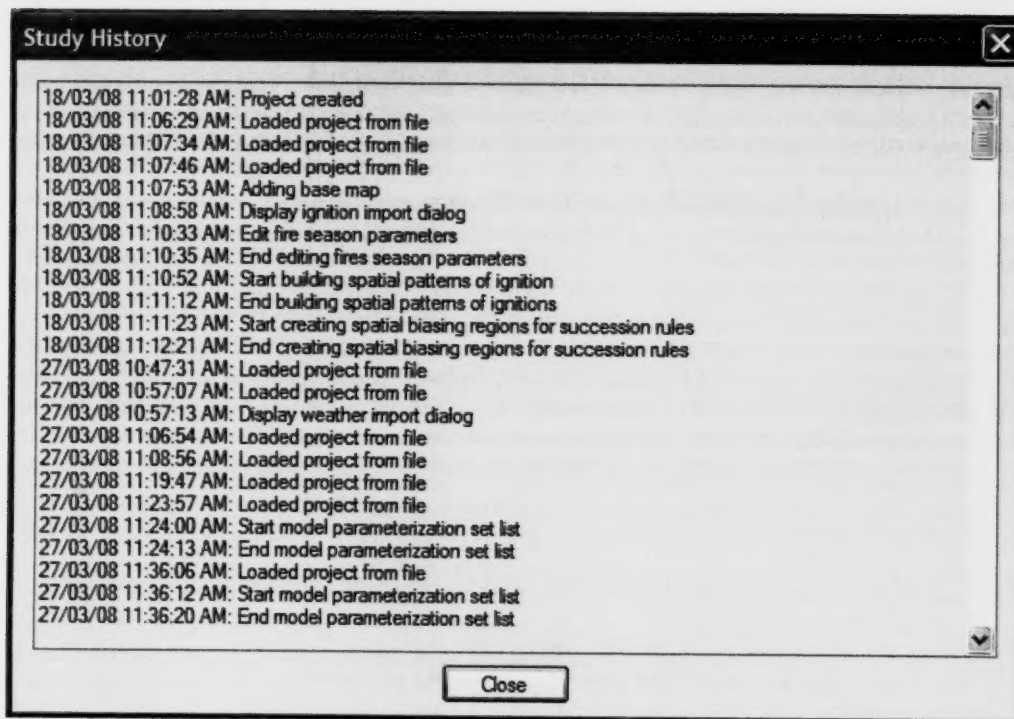
- Provide a study name
- Select a folder in which to store the study information
- If desired, provide a description of the study

BFOLDS toolbox will create a set of folders within the selected folder to store all the spatial data and user assumptions.

The user must also select a simulation goal (see above). Options include:

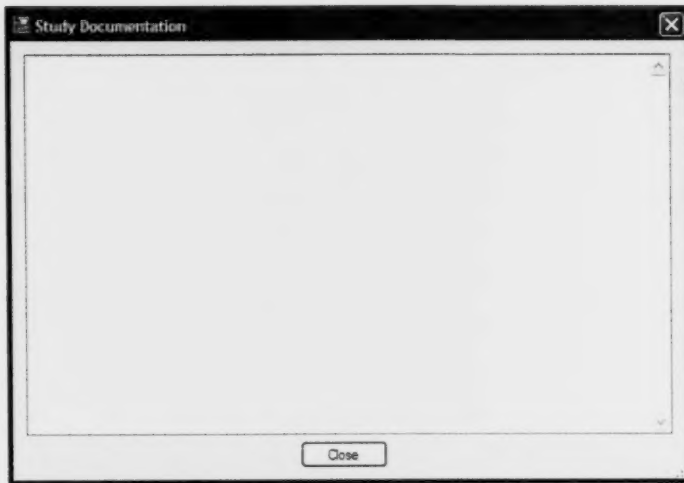
1. *Fire*: The user completes rules for fire only, which will simplify running BFOLDS. However, the simulation period will be limited to 1 year.
2. *Succession*: The user completes rules for succession only. The simulation will cover many years but effects of post-fire establishment will not be visible.
3. *Fire and succession*: The user completes all rules for fire and succession.

Study history

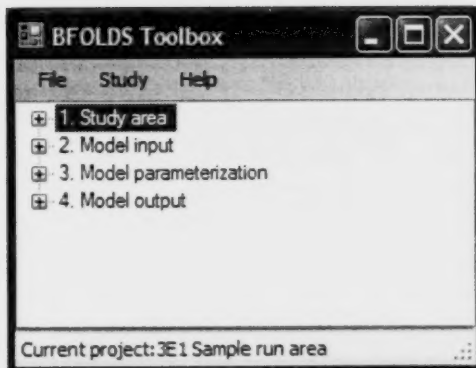


As the user makes changes to a study, i.e., adds spatial data and creates user assumptions, BFOLDS toolbox will automatically add information that reflects these changes to the *Study History* window (see above). This window will show when rule sets were created and edited or new data were imported or deleted, as well as the last time a project was opened.

Study documentation



The BFOLDS toolbox *Study documentation* window (see above) allows the user to add notes to a project. Any text information can be entered, such as data sources, study contacts, etc.

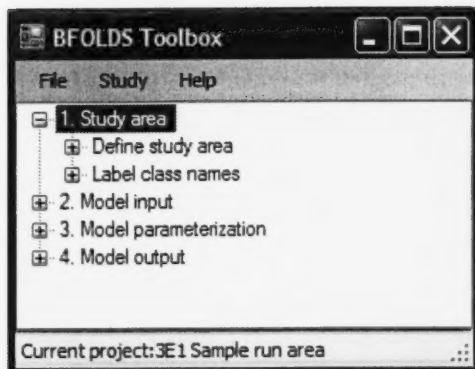


After the user has created or opened a study, the BFOLDS toolbox window (left) will display the major study stages:

- *Study area*
- *Model input*
- *Model parameterization*
- *Model output*

The status bar at the bottom of the window displays the name of the study, which in the above example is *3E1 Sample simulation area*.

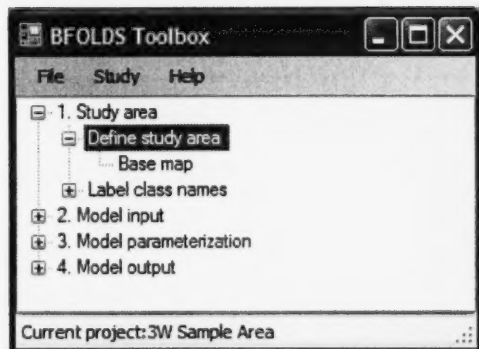
3.5. Study area



If the user selects *Study area*, the following displays (see left):

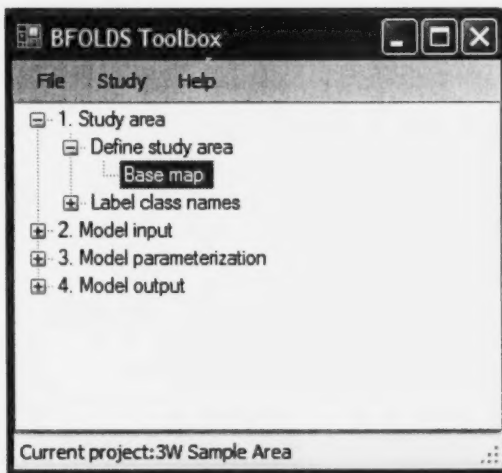
- *Define study area*: The user selects + to expand the tree to enter information about the study area's spatial extent.
- *Label class names*: The user selects + to expand the tree to enter the labels for the values used in the spatial data.

3.5.1. Define study area



Under *Define study area* (see left), the user provides information about the study area location, under the category *Base map*.

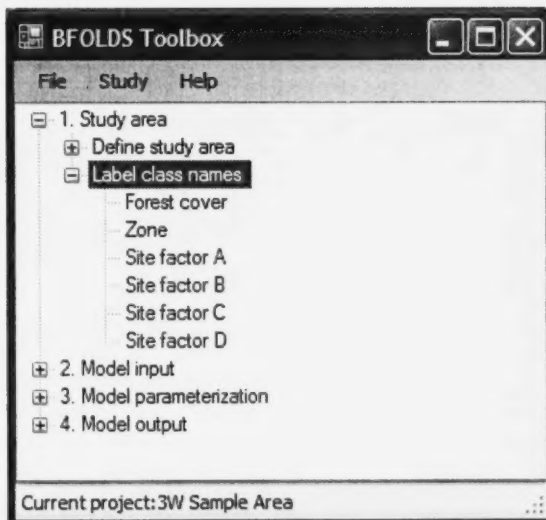
3.5.1.1. Base map



Under *Base map* (see left), the user imports an ASCII GIS file that indicates to BFOLDS 1.0 the extent at which it will be operating. The base map must be imported before any other spatial data layers. The pixels in this file can have 3 available values:

- *No data* (usually -9999): BFOLDS uses this value to identify where data is not available in the study area, such as no data, or areas that cannot burn, such as water and rock
- 1: BFOLDS uses this value to identify the study area
- 2: BFOLDS uses this value to identify the buffer around the study area

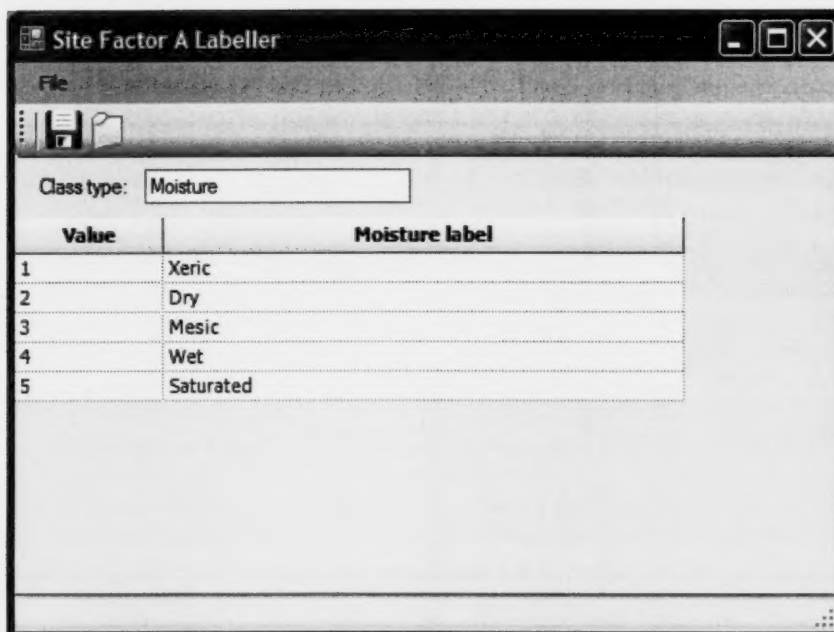
3.5.2. Label class names



Under *Label class names* (see left), the user defines labels to identify the values used in the ASCII GIS files. The user can define the classification for:

- Forest cover (required)
- Zone (required if used)
- Site factors A to D (required if used)

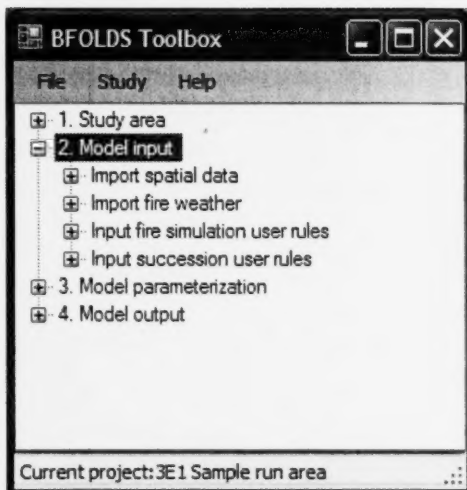
Selecting any of the label class name titles will open the *Data labelling* editor for that data category. For quality control reasons, the user must classify data layers before importing any spatial data. An example of a data labelling editor, which is used to change label class names, is provided below.



The labelling editors (see *Site factor A labeller* above) allow the user to classify the GIS values within BFOLDS 1.0. After an editor is open, the user can enter labels to identify each value in the row. No two values can have the same label or BFOLDS Toolbox will not save the file. When entering data to label values, for example, in the *Site factor A labeller*, the user need only provide values from 1 to 5, if those are the only values used in the spatial data. The other label values can be left empty. In the above example, *Site factor A* was assigned the label *Moisture*, and its five values range from xeric to saturated.

The *Forest cover labeller* has values from 1 to 30 and zones from 1 to 10. All other editors are limited to values 1 to 5.

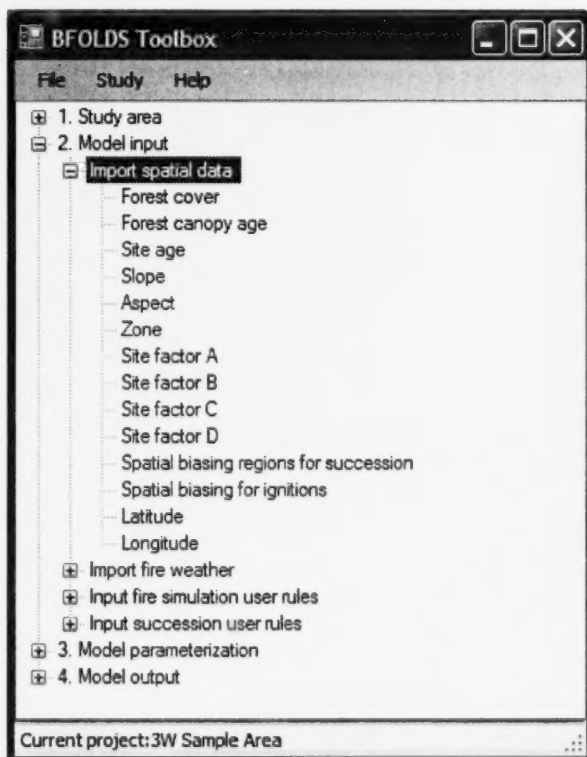
3.6. Model input



If the user selects the + beside *Model input*, the following displays (see left):

- *Import spatial data*
- *Import fire weather*
- *Input fire simulation user rules*
- *Input succession user rules*

3.6.1. Spatial data



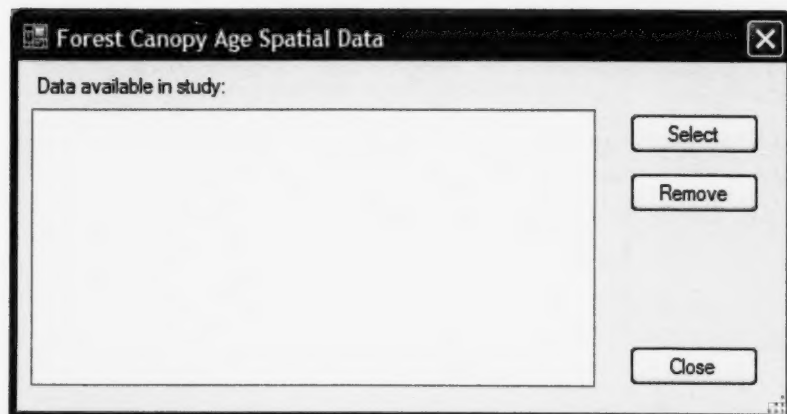
Under *Import spatial data* (see left), the user can import all the spatial data needed to use BFOLDS 1.0. Before importing any spatial data, users must define a base map (see Section 3.5.1.1) and label class names (see Section 3.5.2.).

During importing, BFOLDS toolbox will validate the spatial data to ensure BFOLDS will operate correctly. During this validation, it will ensure that:

- The data layers are proper ASCII files
- The extent of the ASCII files is consistent (rows and columns match the base map)
- The spatial location is the same for all the input files

- The number of values match the values used in the label class editors; i.e., all values have been defined
- Valid data exists for each pixel where a data pixel exists in the forest cover

The types of spatial data that BFOLDS can import are forest cover, forest canopy age, site age, slope, aspect, zone, site factors, spatial biasing regions for succession, spatial biasing for ignitions, and latitude and longitude.

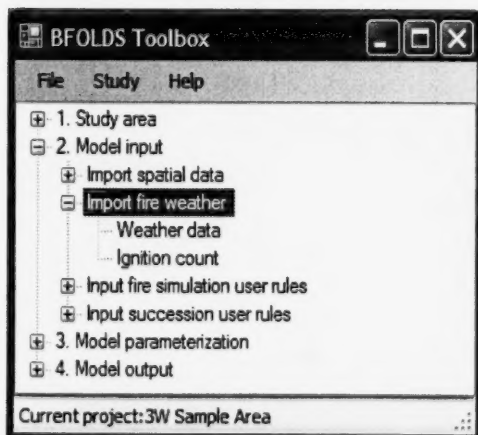


After the user selects the spatial data types to import, the above window displays. The user can:

- Choose *Select* to import new ASCII GIS data into the study
- Choose *Remove* to remove the selected file from the study.

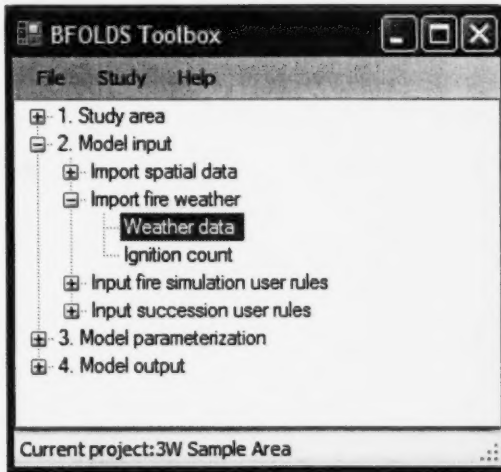
If no data layers have been entered, the box will be empty (see above); otherwise names of imported files will be visible.

3.6.2. Import fire weather

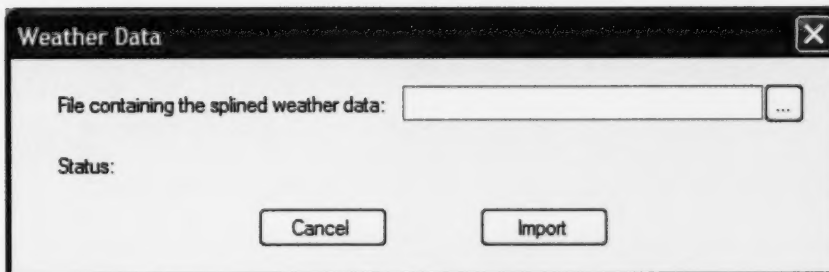


Under *Import fire weather* (see left), the user can import weather data for BFOLDS to use in fire simulations. The user selects the + to see more details.

3.6.2.1. Weather data

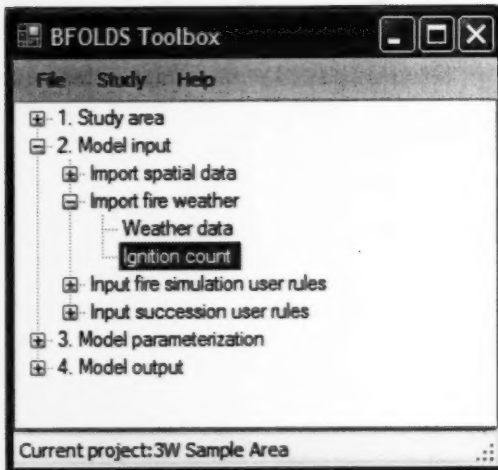


Under *Weather data*, the user can import weather data into BFOLDS. The model needs splined weather data for the period of planned simulation. This weather data can be real or simulated as user assumptions.



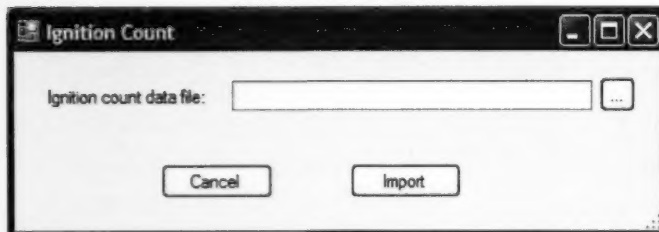
Under *File containing splined weather data* (see above), the user must specify what file to import in the required format (contact flep@ontario.ca for the appropriate splining procedures).

3.6.2.2. Ignition count

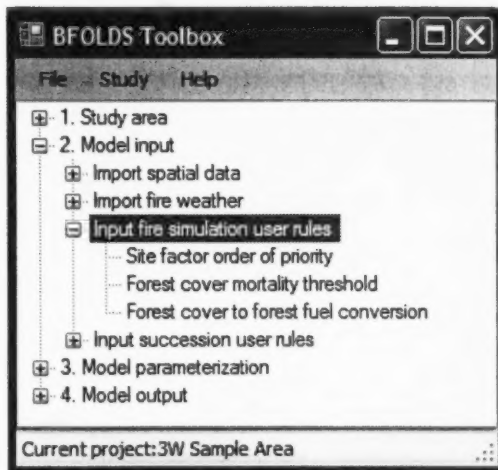


Under *Ignition count* (see left), the user imports daily ignition count data into the study (see section 2.1.7 for details about required data format).

Under *Ignition count data file* (see below), the user identifies the location of the data file.



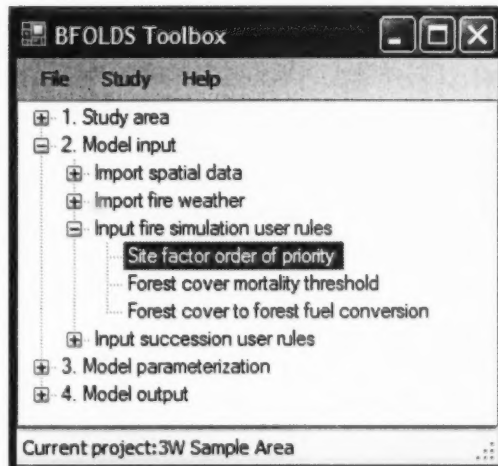
3.6.3. Fire simulation



BFOLDS uses two sets of rules to simulate fire; these rules help to determine how BFOLDS coverts forest cover to forest fuel and when a fire becomes stand replacing, which will affect fire intensity and spread.

Under *Input fire simulation user rules* and *Input succession user rules*, the user can input these rules as detailed in the sections below.

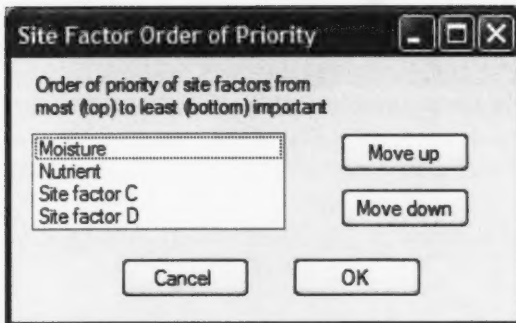
3.6.3.1 Site factor order of priority



Under *Site factor order of priority* (see left), the user can change the relative importance of site factors. Users may select up to four site factors (as explained under 2.1.4.2.), and may include data layers such as eco-sites, site classes, soil moisture, or soil nutrients.

These, in the order of priority (relative importance) decided by the user, affect forest succession and/or forest fire simulation. All site factors are nested under forest cover and zone, respectively. They are subsequently nested within each other based on the user-selected order of priority. Factors with higher order of priority nest the lower priority factors within.

The order of priority could be different or same with respect to forest succession and fire simulation processes. For example, assuming the site factors A, B, C and D for fire simulation the nesting order might be A, C, D, and B; for succession simulation it might be C, A, B, and D. In the example below, user has assigned moisture as the most important factor, followed by nutrient. The ensuing nesting order is moisture(nutrient). Site factor C and Site factor D are not used.



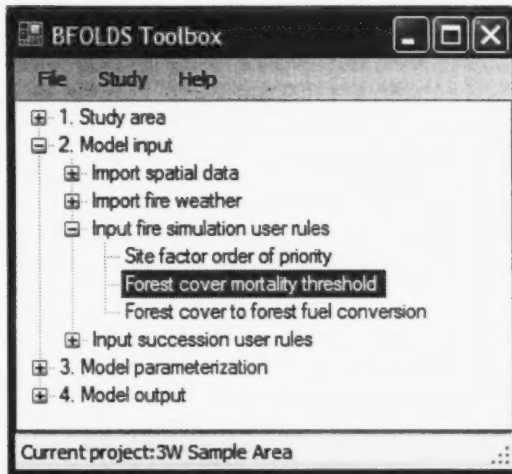
For example, when BFOLDS is using rules (user assumptions) that govern forest succession and forest fire, it will be guided by a given pixel's: forest cover, zone, and site factors (up to 4).

BFOLDS will keep moving up through the hierarchy's levels until it gets to the forest cover. If no forest cover exists BFOLDS will show an error and stop the simulation. The user does not have to provide detailed rules for everything, but it is best to create generalized rules for every forest cover type and then create increasingly detailed rules afterward.

If the user provides 30 forest cover classes, he/she will have to create at least 30 rules for each of the following categories: forest cover mortality threshold, forest cover to forest fuel conversion, post-fire establishment, and natural succession. The maximum detail allowed by BFOLDS and the BFOLDS toolbox is 388,800 ($=30 \times 9 \times 5 \times 5 \times 5 \times 5$) user rules for each category.

Important: Due to the succession algorithm structure, if the user creates a forest cover rule to the Site factor D level of detail, he/she must do the same for all other forest cover classes. However, the same is not true for fire assumptions.

3.6.3.2. Forest cover mortality threshold



As BFOLDS simulates a fire burning through the landscape, it generates the fire intensity. Each fire starts with an intensity of 1 kW/m, and as the fire spreads, the intensity increases. Under *Forest cover mortality threshold* window (see left), the user determines at what intensity threshold the fire becomes a stand-replacing fire for pixels, based on site conditions. Pixels burned with a fire intensity below the threshold will behave as unburned pixels the following year. Pixels burned with a fire intensity equal to or above the threshold behave as subject to a stand-replacing fire.

To determine stand-replacing fires, the user must also make 1 of 2 possible assumptions about the forest cover mortality threshold level they have set:

- BFOLDS considers all pixels subject to intensities that equal or exceed the forest cover mortality threshold values dead and initiates simulation of post-fire establishment.
- BFOLDS assumes all pixels subject to intensities lower than the forest cover mortality threshold values survive and are eligible to burn in the next simulation year.

Forest Cover Mortality Threshold

File

Forest cover: PrDom Zone: Zone1

Moisture	Nutrient	Site factor C	Site factor D	Site age (Inclusive)	Mortality threshold (kw/m2)
Mesic	Organic	Not used	Not used	600	1000

To modify these assumptions for any forest cover-zone combination, the user must select the desired forest cover and zone in the corresponding field at the top of the *Forest cover mortality threshold* window (see above). The editor will update the table with the data for the selected forest cover and zone combination. To make a valid forest cover mortality threshold file, the user must define at least one entry for each forest cover in the *Forest cover* list and the *Not used* value for the *Zone* list.

The user can add or remove rows in the table by selecting the appropriate buttons on the toolbar.

Exception: If the user does not provide a forest cover mortality threshold file, the forest cover mortality threshold for all cover types will be 0, and wherever the fire spreads, it will be considered a stand-replacing fire.

For each entry in the *Forest cover mortality threshold* table (above), the user must define the following fields:

- *Site factors A to D:* Enter the values that will identify the row; the valid values range is defined in the *Label class names* editor. If no labels are provided, only the *Not used* option will be available.
- *Site age:* Enter the maximum site age that will identify the row.
- *Fire intensity (kW/m):* If all the other conditions in the row are found and fit within the ranges, then the stand-replacing fire intensity for this row will be this value. BFOLDS will consider anything equal to or above this value a stand-replacing fire for the pixel.

After the user has made all changes or modified all values, he/she can select *Save* and then *Close* to exit the *Forest cover mortality threshold* window.

Sample scenario for 1 forest cover type with 4 entries

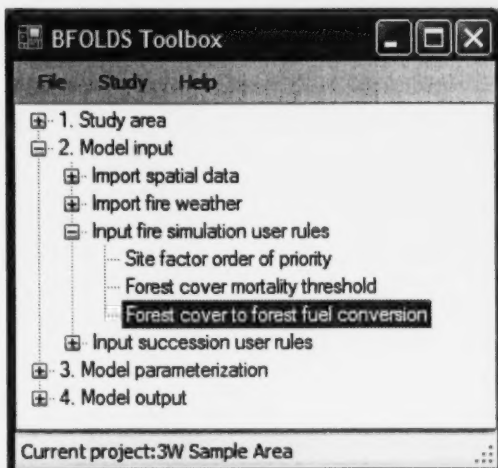
	Zone	Site age	Site factor A	Site factor B	Site factor C	Site factor D	Fire intensity (kW/m)
Entry 1	not used	35	not used	not used	not used	not used	500
Entry 2	1	400	not used	not used	not used	not used	1000
Entry 3	2	400	dry	not used	not used	not used	1250
Entry 4	2	400	wet	not used	not used	not used	1500

Entry 1: The first entry groups zones 1 and 2 together using a *Not used* value because from ages 0 to 35 all Site factor 1 levels should operate similarly, and a fire would need to be 500 kW/m to be considered stand replacing.

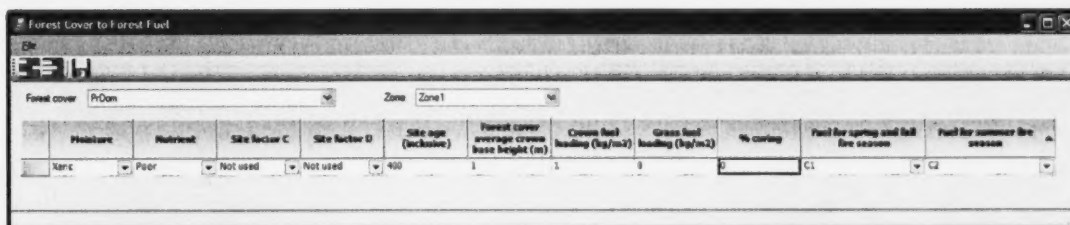
Entry 2: This entry defines threshold fire intensity for site ages 36–400 yrs in Zone 1. All Site factor levels operate similarly, and a fire would need to be 1000 kW/m to be considered stand replacing.

Entries 3 and 4: These entries both work in zone 2 between site ages 36 and 400 but have been divided so that one entry is for a dry Site factor 1 and the other is for a wet one. In this zone and with site ages 36–400 yrs, forest cover behaves differently depending on the site factor 1 values.

3.6.3.3. Forest cover to forest fuel conversion



Under *Forest cover to forest fuel conversion* (see left) the user decides which forest fuel to use when a fire is burning on the landscape, based on forest cover, zone, site age, site factors A to D, and fire season. BFOLDS uses the selected fuel type to determine the fire's spread rate and intensity.



To modify a table, the user selects the *Forest cover* and *Zone* at the top of the *Forest cover to forest fuel* window (above). The editor will update the table with the data for the selected forest cover and zone combination. To make a valid forest cover to fuel type file, the user must define at least one entry for each forest cover in the *Forest cover* list and the *Not used* value for the *Zone* list.

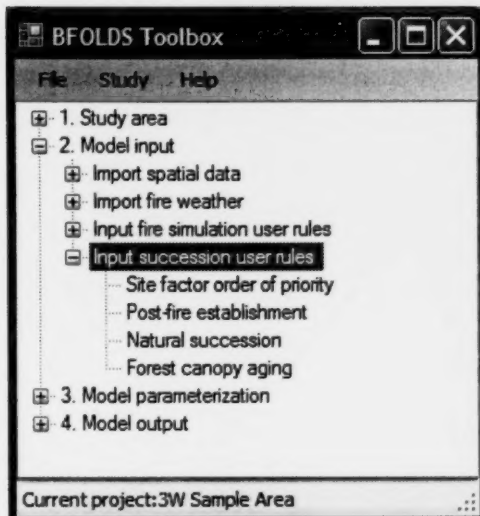
Add or remove rows in the table by selecting the appropriate buttons on the tool bar.

For each entry in the table (see above), the user must do the following:

- *Site age*: Enter the maximum site age that will identify the row. For example, if 2 rows are used, one with a value of 20 and another with a value of 400, the selection process will select the first rule if the site age is less than or equal to 20. Otherwise, it will use the rule with the site age of 400.
- *Site factor A to D*: Enter the site factor values that will identify the row; the valid values range is defined in the label class name editor. If no classification has been provided, only the *not used* option will be available.
- *Forest cover average crown base height*: Enter the forest cover average crown to base height (the height above ground before the live canopy begins; does not apply to 01a grass and 01b grass fuel types).

- *Crown fuel loading:* Enter the crown fuel load in kg/m² (does not apply to 01a grass and 01b grass fuel types).
- *Grass fuel loading:* Enter the grass fuel load in kg/m² (applies to 01a grass and 01b grass fuel types only).
- *% curing:* Enter the proportion of cured or dead plant material in a grassland fuel complex (applies to 01a grass and 01b grass fuel types only).
- *Fuel for spring and fall fire season:* Enter the fuel that will be used for spring and fall fire season.
- *Fuel for summer fire season:* Enter the fuel that will be used for summer fire season.

3.6.4. Input succession user rules



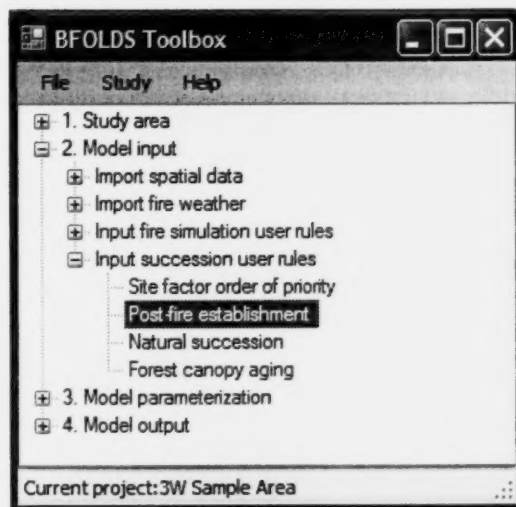
Under *Input succession user rules* the user has four steps to follow.

The first step, *Site factor priority*, is identical to that step as described under *Input fire simulation user rules* (see section 3.6.3.1).

The other steps are required to define the three sets of forest cover transition matrices in BFOLDS (see left):

1. Post-fire establishment
2. Natural succession
3. Forest canopy aging

3.6.4.1. Post-fire establishment



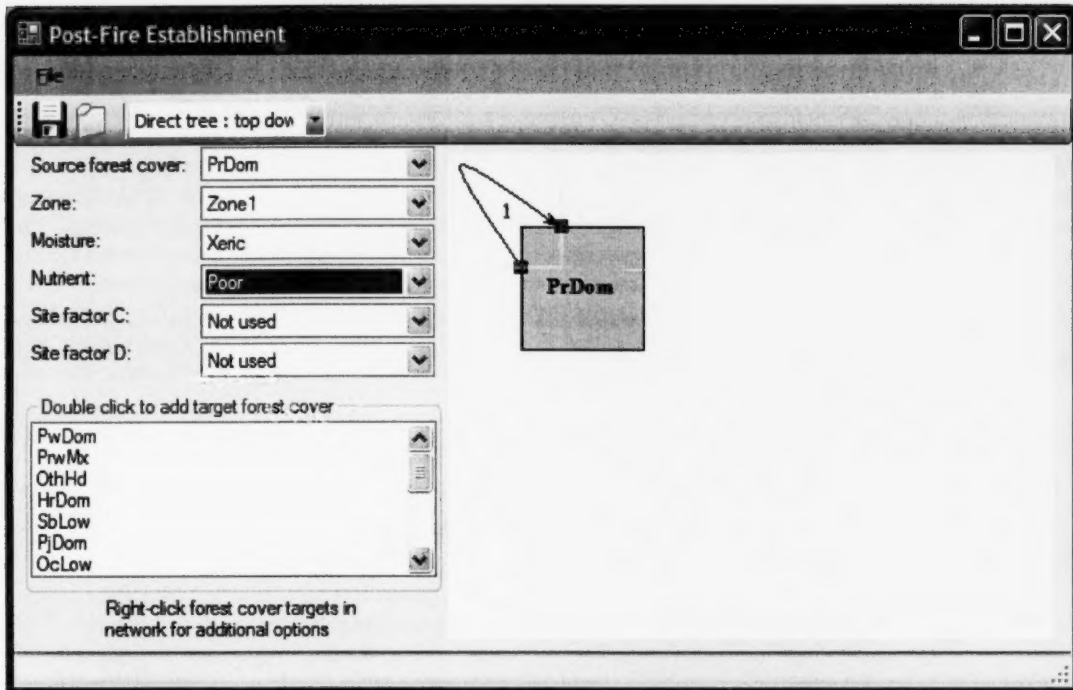
When BFOLDS is simulating a fire burning across the landscape, it will reset the site age of all burned pixels to 0. After the fire simulation, it will simulate succession using post-fire succession rules for all the pixels that have burned with fire intensity at or above the stand-replacement threshold. Use the *Post-fire establishment* editor (see left) to design these rules.

BFOLDS selects the post-fire establishment rules using the following information:

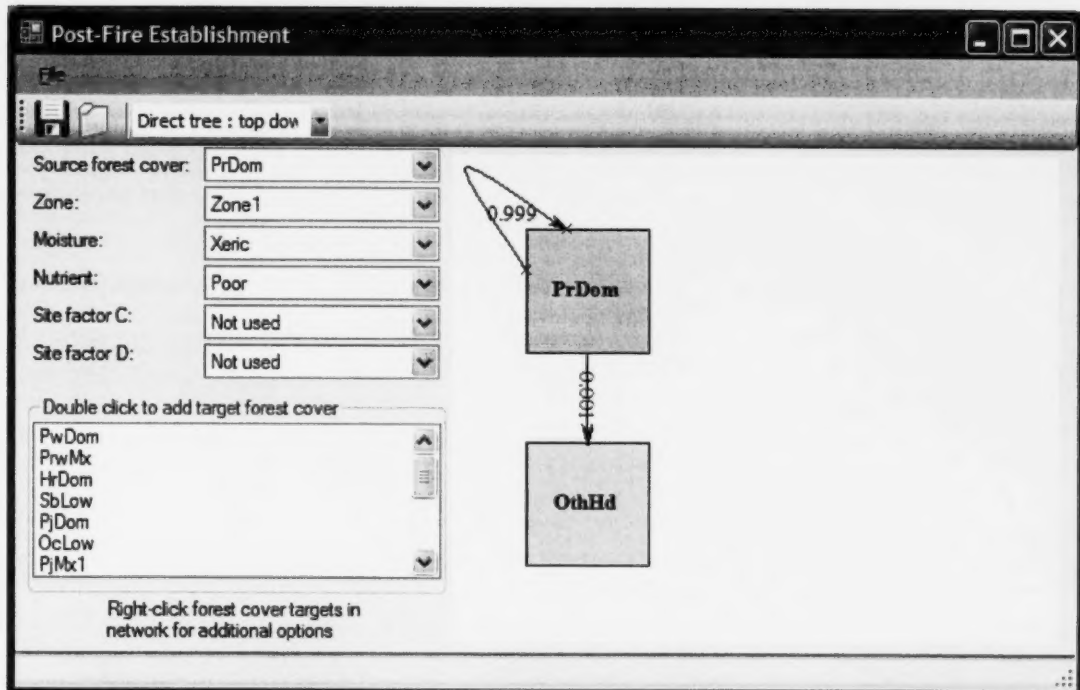
- What was the forest cover of this pixel before the burn?
- What zone is this pixel in?
- What are the pixels' values for site factors A to D?

The user should answer these questions once for every forest cover, zone, and site factors A to D combination for which knowledge is available.

If the user does not create rules for every combination, and BFOLDS tries to find them but does not, it will look for an alternate set of rules. As discussed in Section 3.6.3.1, it is always best to create rules at the most basic level. Presently, these data cannot be directly imported from other formats.



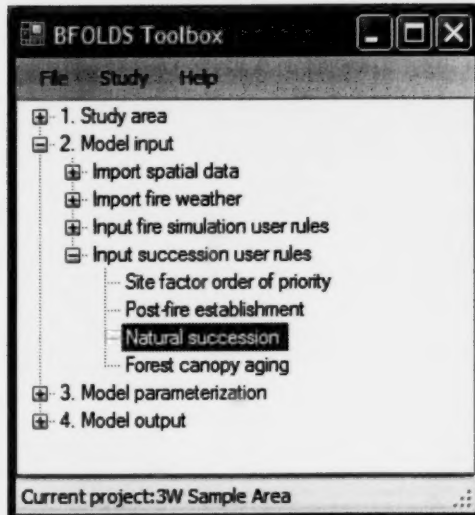
To create a rule, the user must enter the *Source forest cover* (see the hypothetical example above) and the other site conditions that require a rule. The *Post-fire establishment* editor will display any rules already created. Otherwise it displays as above with the source forest cover linking to itself, indicating that if the forest cover in this pixel burns, it will always succeed to itself. The arrow will have a probability value of 1.



If the user double clicks a forest cover class in the list at the left of the *Post-fire establishment* editor, the selected class will appear in the diagram window with a link from the source forest cover (see the hypothetical example above). Right-clicking on a target forest cover box in the diagram will display a menu that will give the user the option to remove an item from the diagram or change the probability for the currently selected forest cover.

When creating succession rules, probabilities must sum to 1.0. If selected forest cover transition probabilities sum to less than 1.0, the source forest cover will be partially self-replacing with probability equal to the difference to 1.0. If the sum of the probabilities for forest cover transitions is higher than 1.0, an error message will indicate that the user needs to adjust the probabilities.

3.6.4.2. Natural succession



Under the *Natural succession* editor (see left), the user creates natural succession rules, which BFOLDS uses to simulate forest succession in the absence of fire.

BFOLDS selects the natural succession rules using the following information:

- What was the forest cover of the pixel?
- What zone is this pixel in?
- What are the pixels' site factors A to D values?

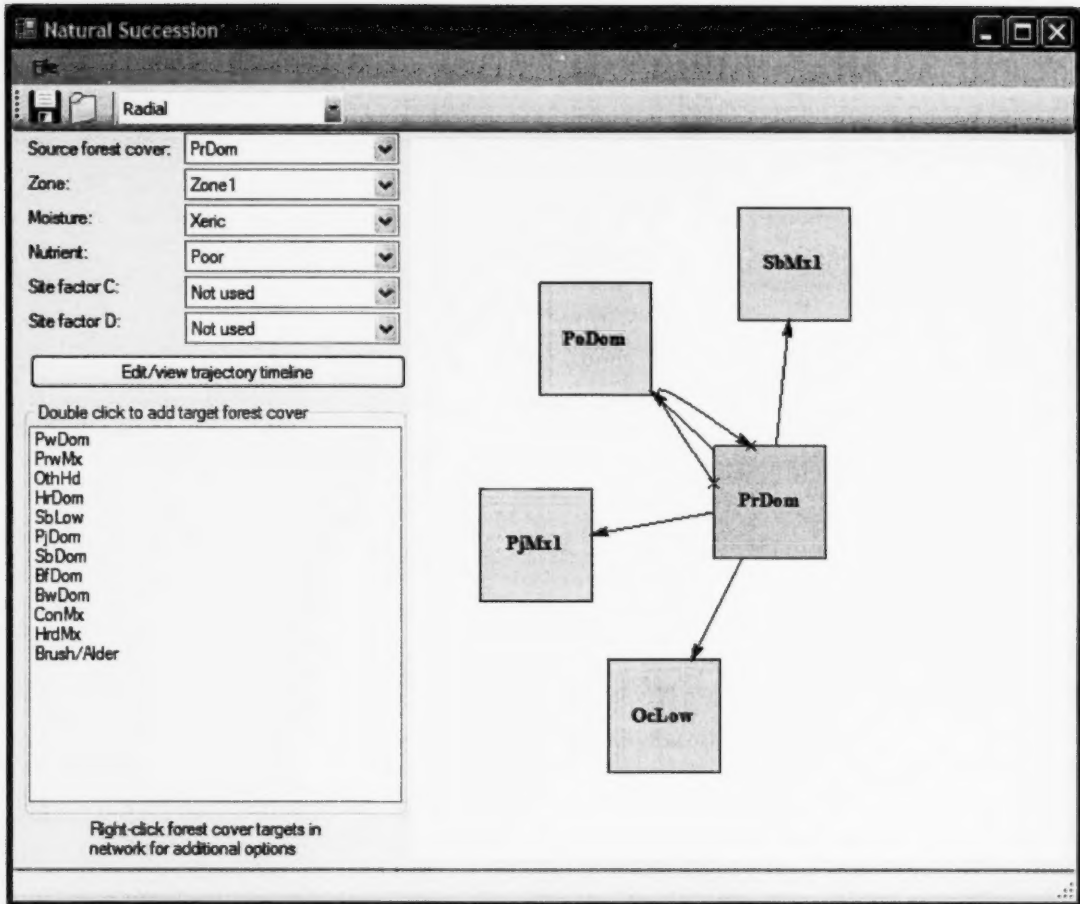
The user should answer these questions once for every combination of forest cover, zone, and site factors A to D, using the best available knowledge.

If the user does not create rules for every combination, and BFOLDS tries to find them but

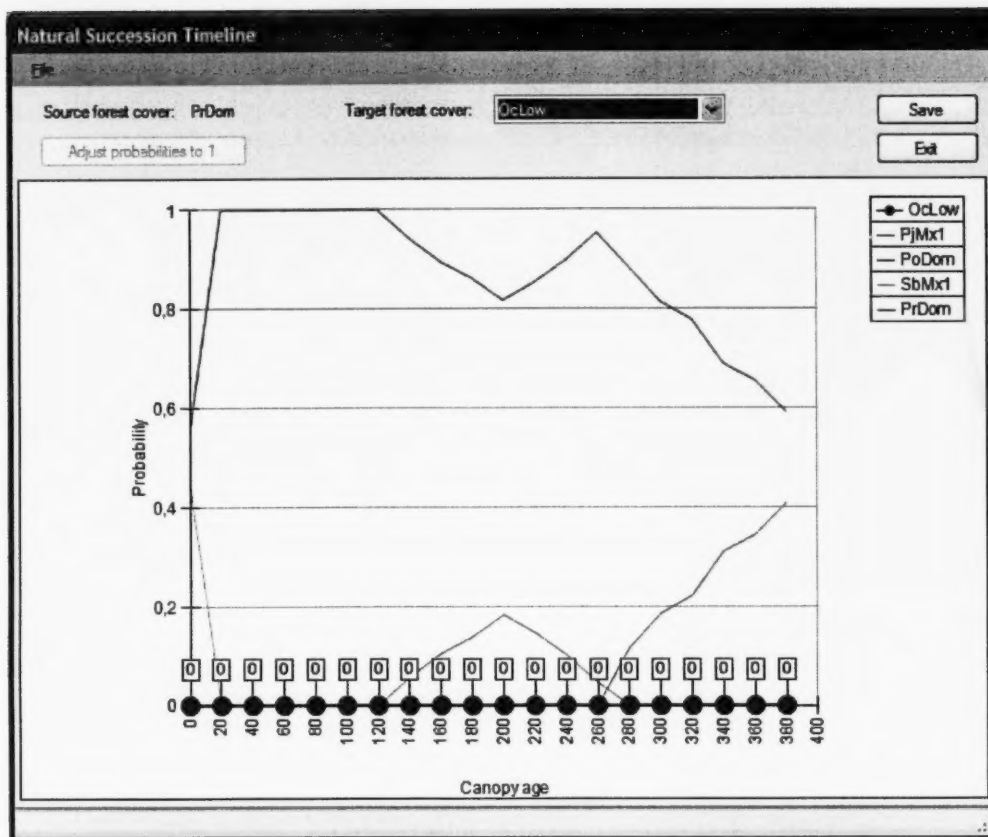
does not, it will look for an alternate set of rules. As discussed in Section 3.6.3.1, it is always best to create rules at the most basic level.

When creating a new rule set for the first time, the user will be prompted to select the succession time step of 5, 10, or 20 years for the rules. Presently, these data cannot be directly imported from other formats.

The *Natural succession* editor works the same way as the *Post-fire establishment* editor, except that probabilities are assigned to the rules differently and will not be visible on the arrows (See below).



When the user right-clicks to select edit probabilities, the *Natural succession timeline* window (see the hypothetical example below) will display.



In the *Natural succession timeline* window, the user can change the probabilities of the targets they assigned in the *Natural succession* window.

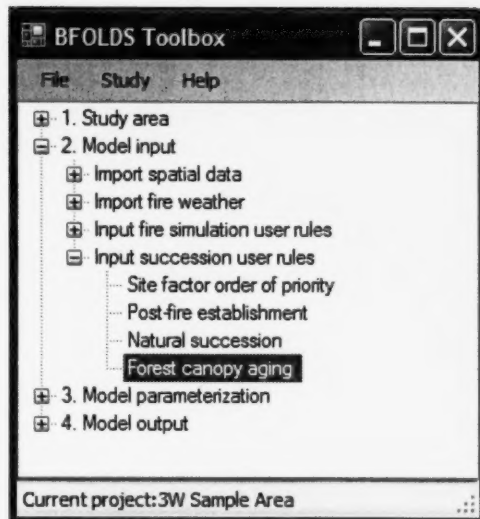
By adjusting the location of the data points on the chart (see above), the user can change the probabilities of the target forest cover classes. Probabilities for each target forest cover must be adjusted individually. After setting the probabilities for the selected forest cover, the user can change to a new forest cover using the *Target forest cover* list at the top of the window.

After selecting a new forest cover class, the user repeats the process described above to change the probabilities, which will then appear on the chart. Note that every time the user changes probabilities the *Source forest cover* series will be updated to show the latest probabilities. For example, as the user increases the probabilities at a time step of a target forest cover, the probabilities of the source forest cover will decrease.

The user will not be able to close the window if the probabilities between the source and target forest cover classes do not add to 1. To simplify this process, the user can select *Adjust probabilities to 1* to change the current target forest cover class probabilities to equal 1.

The user can then select to *Save the entered values* and or to *Exit the Natural succession timeline* window.

3.6.4.3. Forest canopy aging



Forest canopy aging (see left) controls the incoming age and maximum age of each forest cover type. In BFOLDS, when a forest cover succeeds the previous forest cover type, it will have an incoming age greater than 0. If the incoming age exceeds the site age, BFOLDS will make it equal to the site age. As a forest cover type ages, BFOLDS will not allow it to exceed the maximum age for that cover type. If a forest cover becomes older than the maximum age, BFOLDS will reset it to the incoming age for that cover type.

Forest canopy aging rules use the following factors:

- What forest cover type is the pixel?
- What zone is the pixel in?
- Which of site factors A to D is the pixel in?

Forest Canopy Aging

Forest cover: PrDom Zone: Zone1

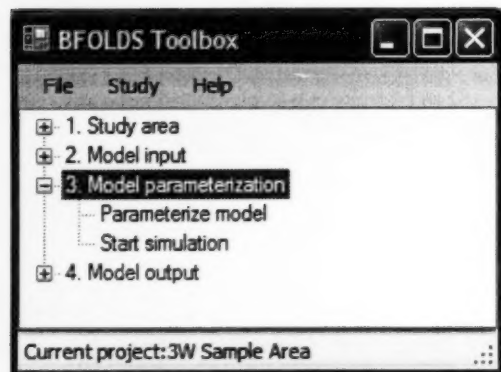
	Moisture	Nutrient	Site factor C	Site factor D	Incoming forest canopy age	Maximum forest canopy age
	Xeric	Poor	Not used	Not used	45	180

The *Forest canopy aging* editor (see above) is similar to the *Forest cover mortality threshold* editor or the *Forest cover to fuel conversion* editor. The user selects a forest cover class and zone combination, and inserts the values in the table. Note that the maximum age must be greater than incoming age for any entry.

In the above example, the forest cover PrDom is given an incoming age of 45 and a maximum age of 180. For example: This means that if PrDom replaces another forest cover type then it will do that with a forest canopy age of 45 years, and if PrDom reaches an age of 180, BFOLDS will reset the age of the forest cover to 45.

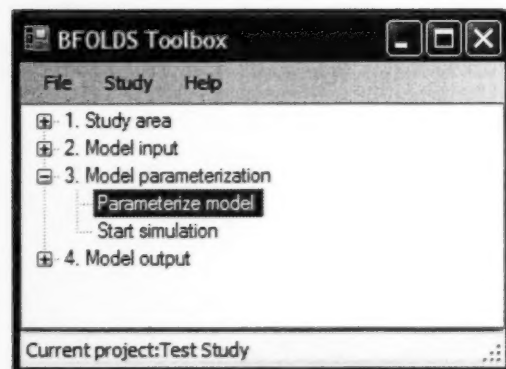
For incoming age, the user selects a value that is greater than 0 and less than the maximum age. The user can add or remove rows in the table by selecting the appropriate buttons on the tool bar.

3.7. Model parameterization



Under *Model parameterization* (see left), the user can create parameterization sets or start a BFOLDS simulation.

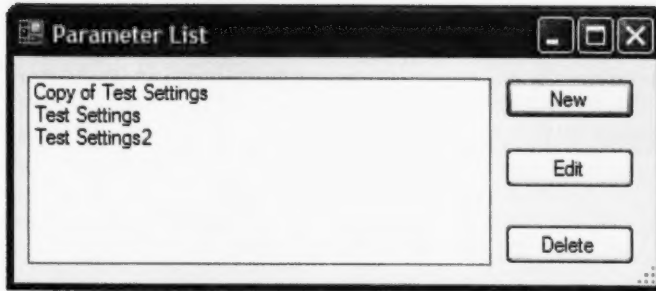
3.7.1. Parameterize model



Under *Parameterize model* (see left), the users can parameterize BFOLDS, that is, create a series of parameter sets, to indicate which files and rules to use in BFOLDS simulations.

To see the effect of different assumptions, for example, using 2 different sets of forest cover to forest fuel conversion rules, the user must provide two parameterization sets.

Selecting *Parameterize model* (see left) opens the *Parameterization list* (see below) window.



The *Parameter list* window (see above) displays all parameterization sets. If the user has not yet created any sets, the window will be empty.

The user selects *New* to create a new set, *Edit* to edit the selected set, or *Delete* to remove the selected set from the list.

Creating/editing a new parameter set

If the user decides to create or edit a parameterization set, a wizard will guide them through the process. At any time, the left bar in the window will display the completed steps and the number of remaining steps. The user may save during or at completion of this step.

Spatial data

Parameterization Set Editor

Select appropriate data layers

Spatial data

Fire simulation

Succession-related rules

Model output

Forest cover data layer: Forest Cover

Forest cover canopy age data layer: age16

Site age data layer:
If left blank, then the forest cover canopy age data layer will be used.

Slope data layer: slope8

Aspect data layer: aspect16

Zone data layer: zone8

Moisture data layer: moisture8

Nutrient data layer: nutrient8

Site factor C data layer:

Site factor D data layer:

Latitude data layer: latitude32

Longitude data layer: longitude32

Exit Save Back Next

For each category of spatial data (see above), the user enters the name of the corresponding data layer from the available list.

Fire simulation

Parameterization Set Editor

Select fire simulation parameters

Spatial data

Fire simulation

Succession-related rules

Model output

Forest cover to forest fuel rules: default

Forest cover mortality threshold rules:
If left blank, a fire intensity threshold of 0 will be used. default

Spatial biasing of ignition data layer:
If left blank, a random ignition placement will be used.

DMC threshold for fire extinguishment: 20

DMC threshold range: 10 %

Fire season start date (dd/mm): 01/04

Summer season start date (dd/mm): 05/06

Summer season end date (dd/mm): 05/10

Fire season end date (dd/mm): 31/10

Exit Save Back Next

The above window allows the user to select and/or enter fire simulation parameters.

Succession-related rules

Parameterization Set Editor

Select forest succession parameters

Spatial data

Fire simulation

Succession-related rules

Model output

Post-fire establishment rules: default

Natural succession rules: default

Forest canopy aging rules: default

Use spatial biasing regions for succession? ☒ Yes ☐ No

Spatial biasing regions for succession layer: region8

Region weights for spatial biasing region. (Enter only the denominator)

Low: (default value of 1/4) 1/ 4

Medium: (default value of 1/3) 1/ 3

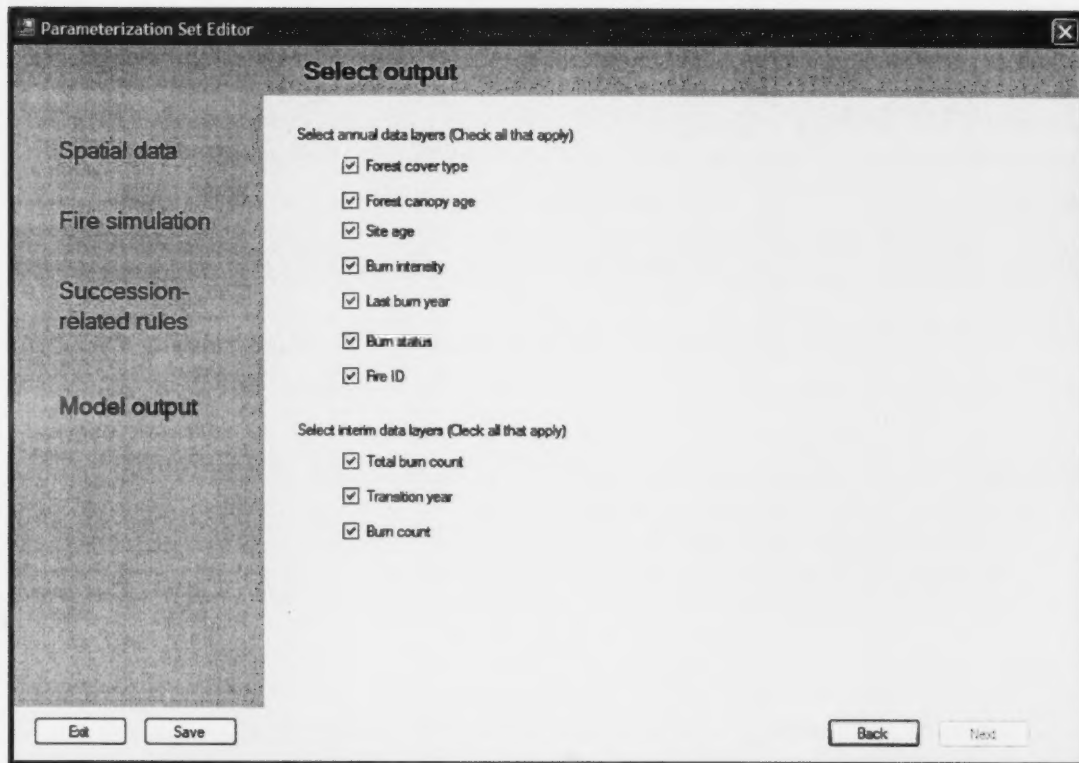
High: (default value of 1/2) 1/ 2

The threshold probability to apply to the spatial biasing regions: 1

Exit Save Back Next

The above window allows the user to select and/or enter forest succession parameters.

Model output



BFOLDS generates many data layers as it runs. Under *Model output* (see above), the user can decide what output to generate. The more layers the user selects to generate, the longer BFOLDS will run, and the more storage space will be needed. The following is information about selecting annual and interim output data layers as shown above.

Selecting annual data layers

The user selects the check boxes beside the desired data layers. If unsure about what output is appropriate, the user should select all the data layers described in the table below.

Primary output image	Description	Filename example
Forest cover type	Forest cover type occupying pixel each year	Forest_cover_rep1_y1
Forest cover canopy age	Age of canopy trees in pixel	Canopy_age_rep1_y1
Site age	Time since pixel was last burned	Age_since_disturbance_rep1_y1
Burn intensity	Intensity values for pixels that burned	Burn_intensity_rep1_y10
Last burn year	Simulation year when last burn occurred for each pixel	Last_burn_year_rep1_y1
Burn status	Denotes that a pixel is burned <u>and</u> the forest cover is destroyed or is not burned	Burned_rep1_y1
Fire ID	Indicates that all burned pixels (regardless of forest cover mortality) belong to the same fire	Fire_id_rep1_y1

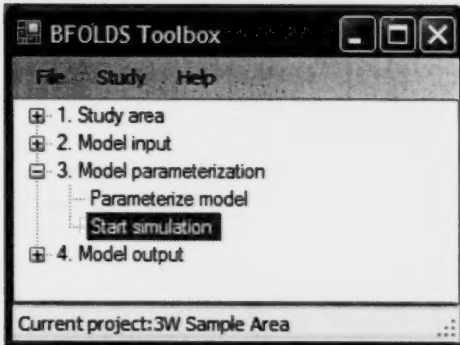
Selecting interim data layers

The user selects the check boxes beside the desired interim data layers. If unsure about what output is appropriate, the user should select all the data layers described in the table below.

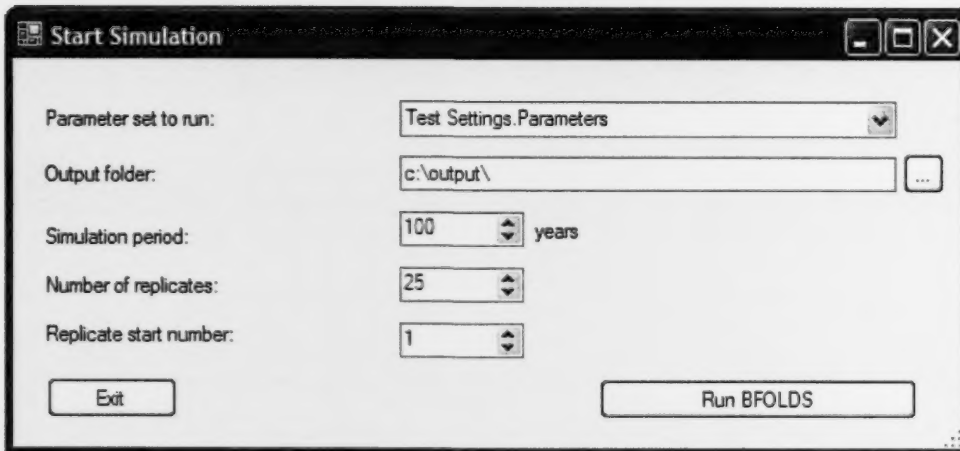
Primary output	Description	Filename example
Total burn count	The total burn count to date for the current replication	Total_burn_count_rep1_y10
Transition year	Simulation year when last forest cover transition occurred	Year_of_transition_rep1_y10
Burn count	Binary image of burn/no burn within 10-year period. Pixels with no forest cover mortality are designated no-burn.	Burn_count_rep1_y10

Appendix I provides a list of all data categories and data sets required to conduct BFOLDS simulations.

3.7.2. Start simulation



After the user has created at least one model parameter set they can select *Start simulation* (see left).



In the *Start simulation* window (see above), the user:

- Selects the parameterization set to use under *Parameter set to run*.
- Selects which folder BFOLDS should use to store the output, including the log files and the primary output under *Output folder*.

The user must ensure that they have adequate hard drive space to store output – BFOLDS does not check. The table below gives several examples of output and associated space requirements.

Forested area in study area	Approximate drive space
2.9 million ha (1 rep, 1 year)	4 MB
2.9 million ha (1 rep, 200 years)	800 MB
2.9 million ha (25 reps, 200 years)	20 GB
15 million ha (1 rep, 1 year)	22.5 MB
15 million ha (1 rep, 200 years)	4.5 GB
15 million ha (25 rep, 200 years)	112.5 GB

- Under *Simulation period*, the user selects the *number of years* for the simulation period.
- Under *Number of replicates*, the user selects the *number of replicates* for the simulation.
- Under *Replicate start number*, the user specifies the number that BFOLDS should begin at when labelling replicates for storing the output.

After entering the information required under *Run model parameter set*, the user can select *Run BFOLDS* to start the simulations.

The screenshot shows the BFOLDS 1.0 application window. At the top, the title bar reads "BFOLDS 1.0". Below the title bar, there are input fields for "Replication:" (set to 1), "Year:" (set to 15), and a "2" in a box. Below these, there is a row of 10 checkboxes for replicates, with the 5th one checked. To the left of this row are buttons for "Exit" and "Stop". Below the checkboxes, there is a "Year:" label and a "5" in a box. Below this, there is a "Log" button and a "Number of fires" label with a "5" in a box. The main text area displays the following output:

```

Unbiased transition burn patch count: 0
Biased transition calculation count: 713440
spv adjustment count: 713440
Writing snapshot layers
Zip archive named: c:\temp\rep_1_Year_15_project name.zip

Year: 15
Start Time: 28/03/2008 8:07:34 AM
Randomly selected historical data year: 1997
  Reading FWI DMC...
  Reading FWI FFM...
  Reading FWI BUI...
  Reading FWI Wind VP...
  Reading FWI Wind UP...
  
```

At the bottom of the window, there is a "Clear" button and a table with the following data:

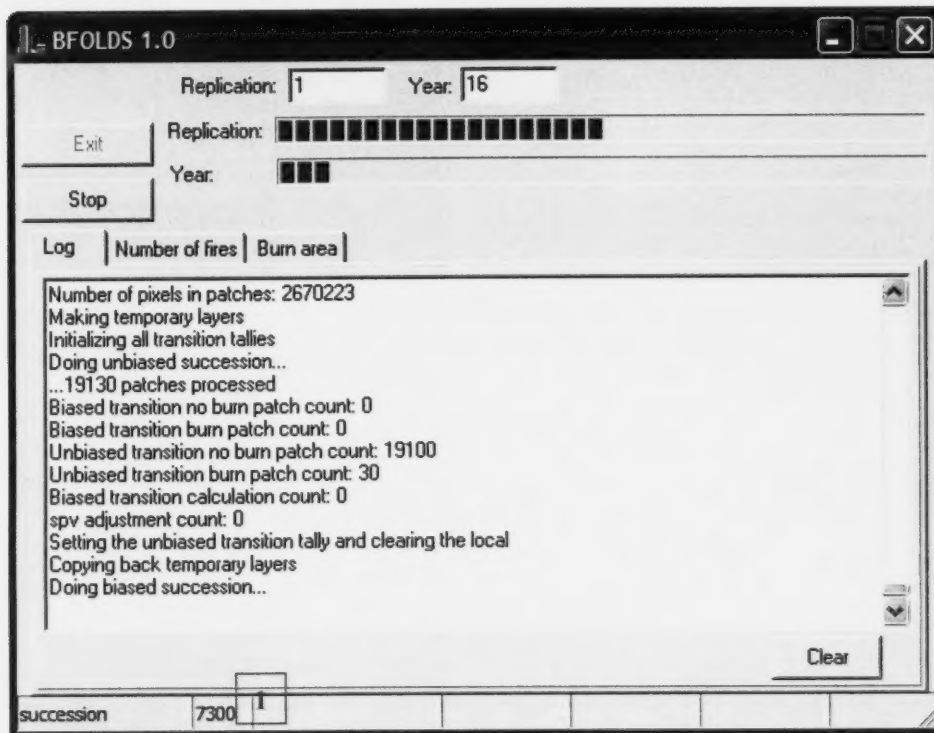
fire	6		176	7	16	8	2903	9	1423	10
------	---	--	-----	---	----	---	------	---	------	----

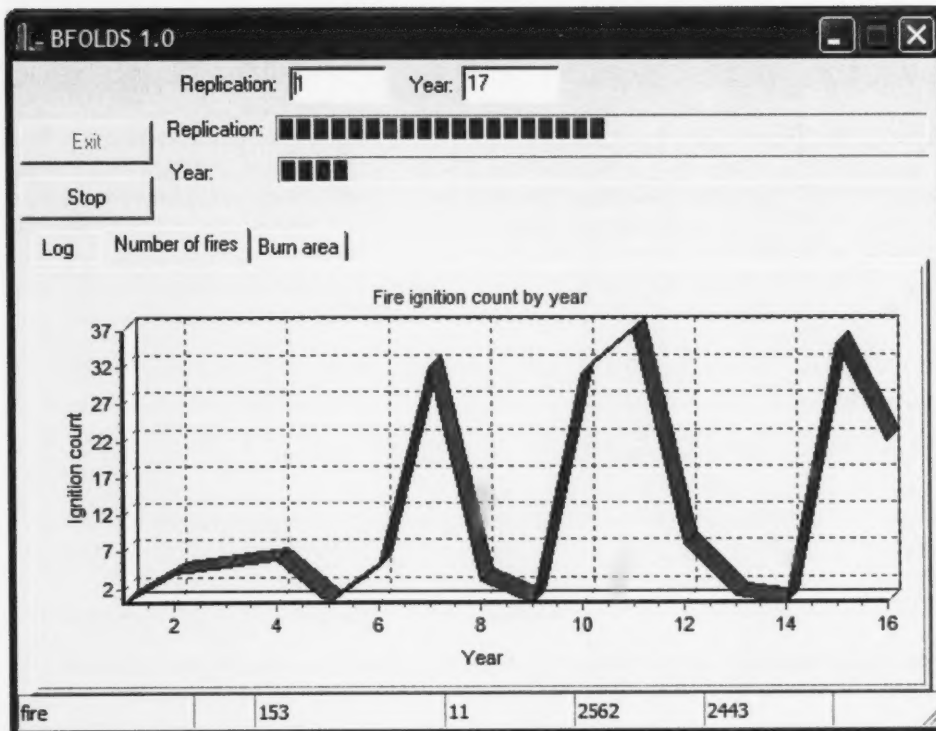
While BFOLDS is running, the user will see a window that outlines the model's actions (see above). This window has 11 features that provide details of a fire season during simulations:

1. Indicates current replication
2. Indicates current simulation year
3. Shows progress of replications and the year completed within the current replication
4. Allows the user to stop the simulation (some tasks may need to finish before BFOLDS can stop). Once a simulation is stopped it cannot be resumed. It must be restarted.
5. Allows the user to switch from *Log* view to the *Number of fires* and *Area burned* within the current replication
6. Indicates what part of BFOLDS is running (fire or succession)
7. Shows the current Julian day of the fire season being processed
8. Shows how many fires ignited during the current model year
9. Indicates how many pixels burned based on the fire intensity threshold
10. Indicates how many events are left in the BFOLDS fire simulation event scheduler
11. Provides detailed information about BFOLDS processes

When BFOLDS has completed all the replications, the progress bars [3] are both empty and the last line in the *Log* window [11] indicates that the simulation is complete.

While BFOLDS is simulating forest succession, the information displayed changes; the previous information in 7-10 is replaced by a number (next to the 1 below), which indicates the discrete succession events that have occurred (7300 in this example).

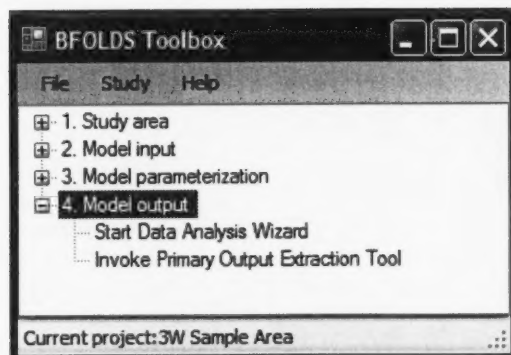




Selecting the *Number of fires* tab allows the user to see the number of fires for the current replication (see above). After BFOLDS completes a replication, it clears this chart.

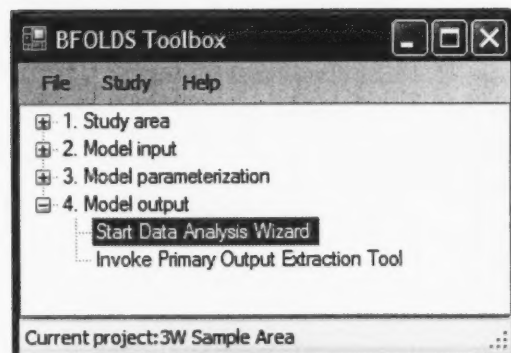
Selecting the *Burn area* tab allows the user to see the area burned for the current replication. After BFOLDS completes a replication, it clears this chart.

3.8. Model output



Under Model output, the user can access the Data Analysis Wizard to generate secondary output and the Primary Output Extraction Tool to extract output data as detailed below.

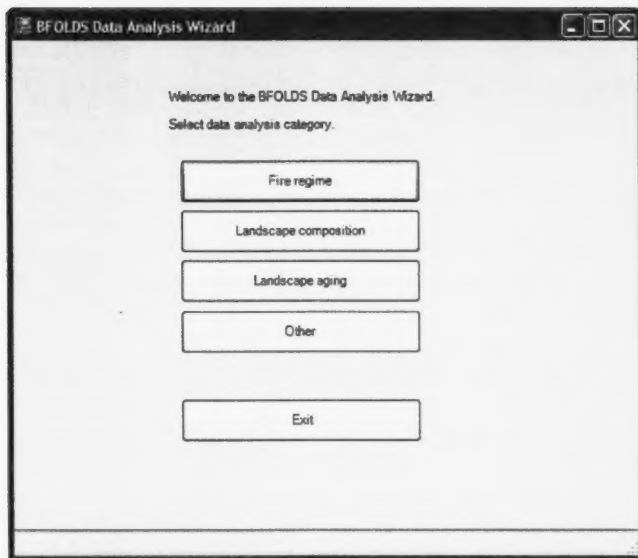
3.8.1. Start Data Analysis Wizard



The BFOLDS toolbox *Data Analysis Wizard* helps the user to generate secondary output. This tool's advantages are:

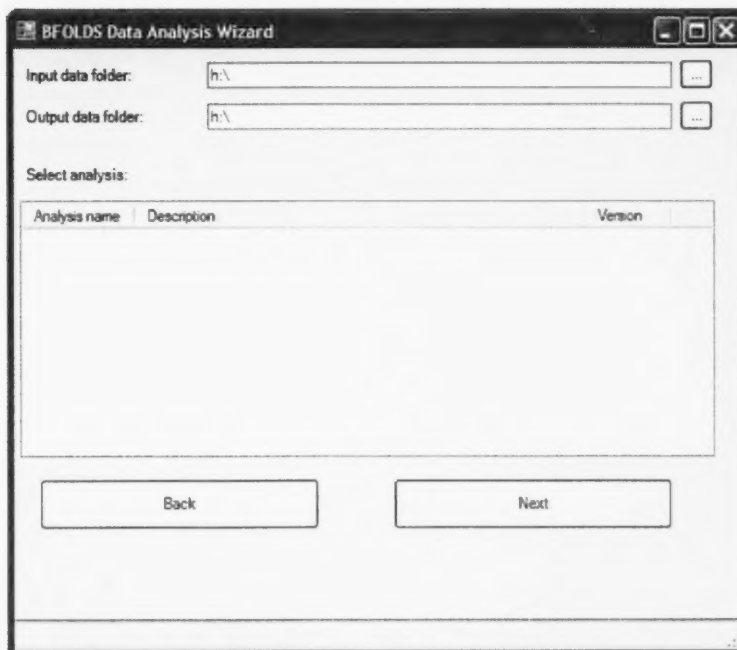
- No GIS skills are needed to do advanced analysis.
- It is a plug-in system, so new analysis methods can be added easily.
- It has a simple user interface.

To develop plug-ins for the *Data Analysis Wizard*, the user may contact the Forest Landscape Ecology Program at flep@ontario.ca for more information.



Using the *Data Analysis Wizard*

After starting the *Data Analysis Wizard*, the user will be asked which type of analysis to perform (see above): Fire regime, Landscape composition, Landscape aging, or Other (for analyses that do not fall in the former categories).



After selecting the analysis category, the user:

- Selects the location of the input data (BFOLDS output) and the location where the *Data analysis wizard* should store the output data (see above).
- Selects which analysis to perform. The windows that open will differ depending on the analysis method selected. Some methods will initiate input data analysis immediately, while others may require the user to input more parameters.

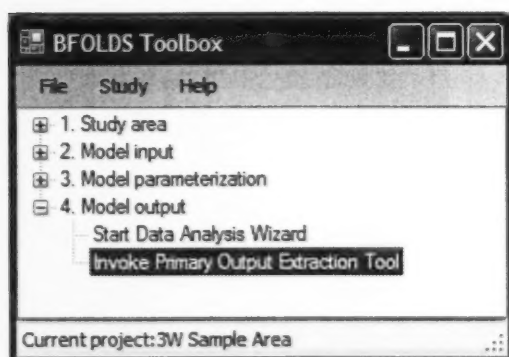
Depending on the analysis, it could take several minutes to several hours to generate secondary output data.

Since new analyses will be added to the *Data Analysis Wizard*, users should contact the Forest Landscape Ecology Program at flep@ontario.ca for an updated list of plug-ins.

The output types will depend on the analysis method and the plug-in, and could include:

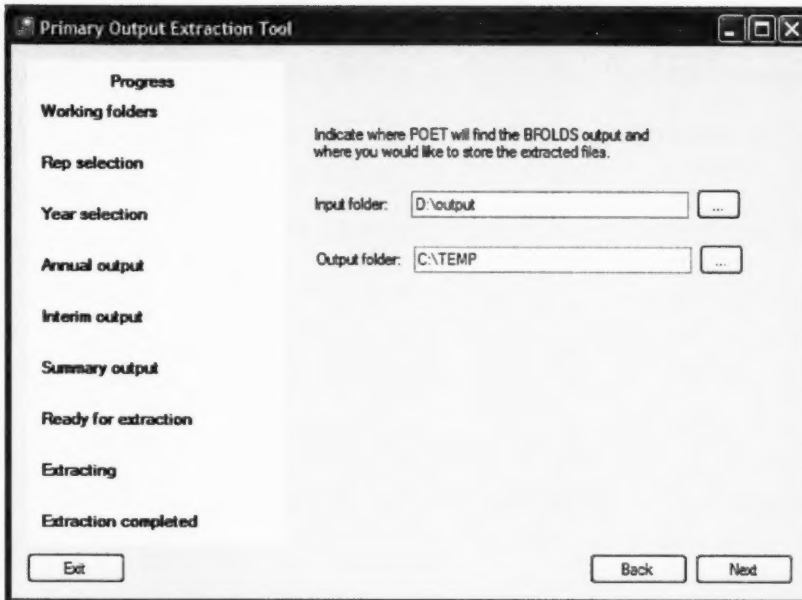
- Maps in ASCII format
- Maps (as JPGs)
- Tabular data
- Charts (as JPGs)

3.8.2. Invoke *Primary Output Extraction Tool*



Since BFOLDS output data is compressed to save space, it can be time consuming to extract. If the user selects *Invoke primary output extraction tool* (see left), BFOLDS toolbox will open a wizard called *Primary Output Extraction Tool*, which will guide them through data extraction for use in GIS software.

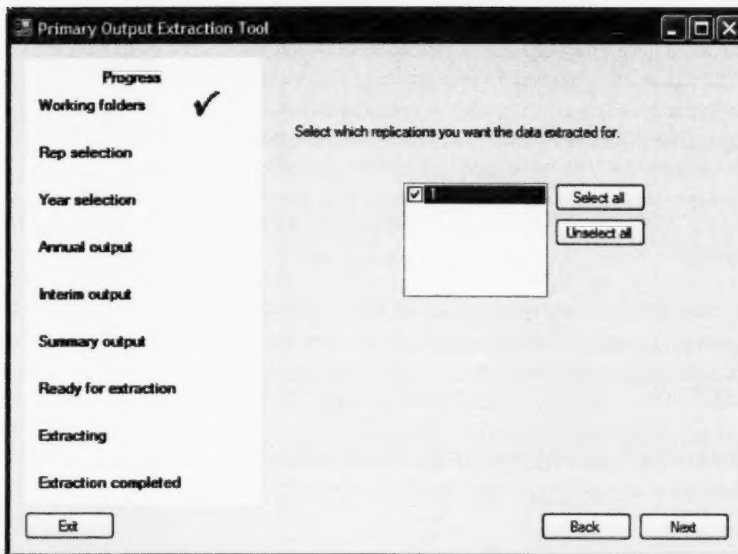
Working folders



Under *Working folders* (see above), the user specifies the location of the BFOLDS input folder containing all the ZIP files as well as where BFOLDS should save output.

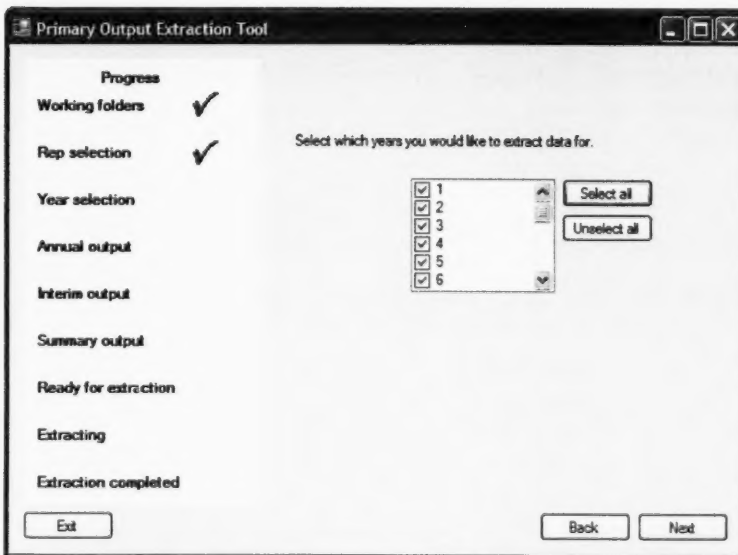
Important: Using different input and output folders on different drives will greatly speed up extraction, especially when working with removable drives, such as a USB external hard drive.

Selecting replications



Under *Rep selection* (see above), the user specifies replicates for which BFOLDS should extract data.

Year selection



Under *Year selection* (see above), the user specifies the years for which BFOLDS should extract data.

Annual output

Primary Output Extraction Tool

Progress

- Working folders ✓
- Rep selection ✓
- Year selection ✓
- Annual output**
- Interim output
- Summary output
- Ready for extraction
- Extracting
- Extraction completed

Select the yearly output to extract:

- ☒ Forest cover type
- ☐ Site age
- ☐ Forest cover canopy age
- ☐ Burned status
- ☐ Fire ID
- ☐ Last burn year
- ☐ Burn intensity

Exit Back Next

Under *Annual output*, the user selects each ASCII file to be extracted. The table below describes the output available for extraction.

Primary output image	Description	Filename example
Forest cover type	Forest cover type occupying pixel each year	Forest_cover_rep1_y1
Site age	Time since pixel was last burned	Age_since_disturbance_rep1_y1
Forest cover canopy age	Age of canopy trees in pixel	Canopy_age_rep1_y1
Burn status	Denotes that a pixel is burned <u>and</u> the forest cover is destroyed or is not burned	Burned_rep1_y1
Fire ID	Indicates that all burned pixels (regardless of forest cover mortality) belong to the same fire	Fire_id_rep1_y1
Last burn year	Simulation year when last burn occurred for each pixel	Last_burn_year_rep1_y1
Burn intensity	Intensity values for pixels that burned	Burn_intensity_rep1_y10

Interim output

Primary Output Extraction Tool

Progress

- Working folders ✓
- Rep selection ✓
- Year selection ✓
- Annual output ✓
- Interim output**
- Summary output
- Ready for extraction
- Extracting
- Extraction completed

Select the interim output to extract:

- ☐ Burn count
- ☐ Total burn count
- ☐ Transition year

Exit Back Next

Under *Interim output* (see above), the user selects the box next to each ASCII file to be extracted. The table below describes the output available for extraction.

Primary output	Description	Filename example
Burn count	Binary image of burn/no burn within 10 year period. Pixels with no forest cover mortality are designated no-burn.	Burn_count_rep1_y10
Total burn count	The total burn count to date for the current replication	Total_burn_count_rep1_y10
Transition year	Simulation year when last forest cover transition occurred	Year_of_transition_rep1_y10

Summary output

Primary Output Extraction Tool

Progress

- Working folders ✓
- Rep selection ✓
- Year selection ✓
- Annual output ✓
- Interim output ✓
- Summary output**

Select the summary output to extract:

- ☐ Max site age reached
- ☒ Total burn count

Ready for extraction

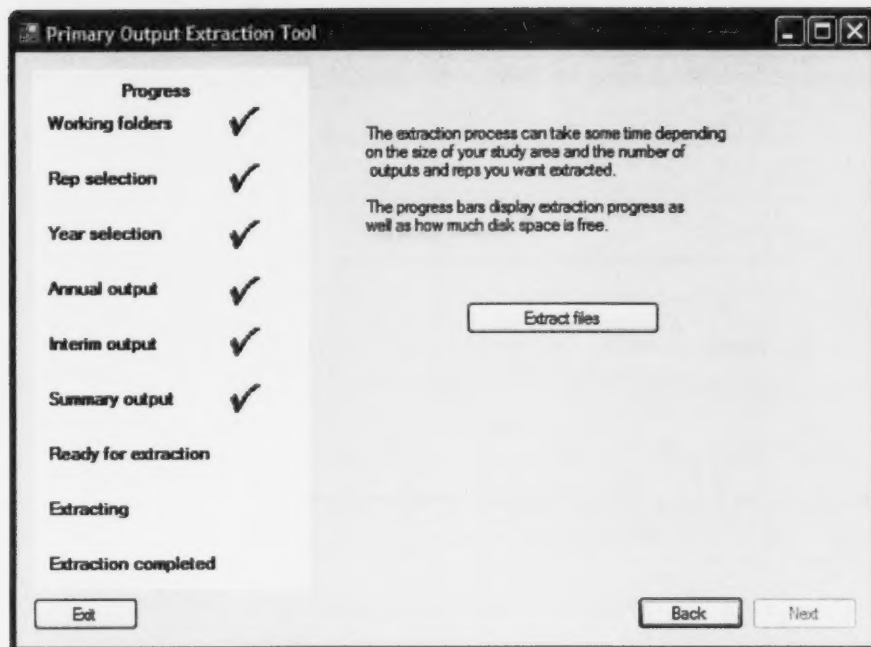
Extracting

Extraction completed

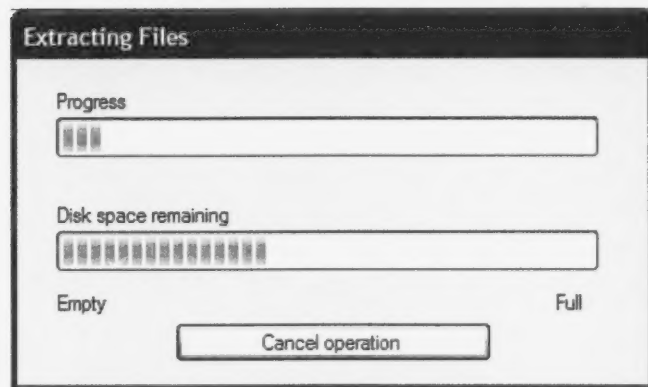
Under *Summary output* (see above), the user selects each ASCII file to be extracted for summary output. The table below describes the output available for extraction.

Primary output	Description	Filename example
Max site age reached	The maximum site age reached during simulation for each pixel	max_burn_age_rep1
Total burn count	The total burn count for each pixel during the simulation	total_burn_count_rep1

Ready for extraction

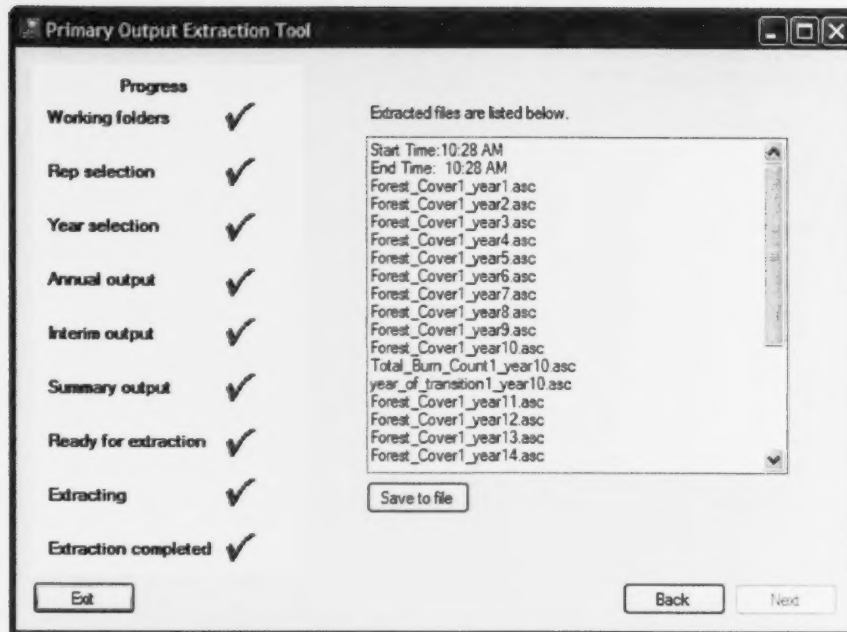


Under *Ready for extraction* (see above), the user selects *Extract files* to start the extraction process. This process can take several minutes to several hours, depending on the amount of data to be extracted and the size of the study area.



As the extraction progresses, the above window will provide information about extraction progress as well as how much disk space remains on the target hard drive.

Extraction completed



After BFOLDS extracts the files, the above window will display. The user can view the extracted files under the *Extraction completed* log.

Appendix I. A final checklist for BFOLDS data required for simulations.

Category	Data set	Completed
Spatial data	Forest cover	
	Forest canopy age	
	Site age	
	Slope	
	Aspect	
	Zone	
	Site factor A	
	Site factor B	
	Site factor C	
	Site factor D	
	Spatial biasing regions for succession	
	Spatial biasing of ignitions	
	Latitude	
	Longitude	
Weather data	Weather data from data points	
	Ignition count	
Fire simulation	Site factor priority	
	Forest cover mortality threshold	
	Forest cover to forest fuel conversion	
	DMC threshold and range for extinguishment	
	Fire season start and end dates	
	Summer season start and end dates	
Forest succession	Site factor priority	
	Post-fire establishment	
	Natural succession	
	Forest canopy aging	
	Succession time step	
Parameters	Select output content	
	Simulation duration (number of years)	
	Number of replications	

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